PSEUDO

Dynamic Pseudo-Relative Permeability Software

for input to the

Eclipse *

Reservoir Simulation Software **

vended by

Schlumberger (GeoQuest)

*   This tutorial is based on Grid version 1999a_1.
** Eclipse is Schlumberger (GeoQuest) software.

Table of Contents (for PSEUDO Tutorial & Coning Comparison)

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Table of Contents (for PSEUDO Tutorial & Coning Comparison)

Thank you for visiting www.EricLaine.com.

The primary purpose of this document is to serve as a memory aid for the author. Thus, the author is also the target audience. (In other words, the quality of the composition is 100% sufficient for me to understand what I wrote.)

The secondary purpose is to share this tutorial with the public. I appreciate the possibility that the general public may have some difficulty understanding the my personal abbreviations and my intuitive logic.

Please send your questions and your suggestions to EricLaine@compuserve.com.

Part of this tutorial is about PSEUDO. PSEUDO is Schlumberger - GeoQuest software for calculating rate-dependent pseudo relative permeabilities (Kr) and rate-dependent pseudo capillary pressures (Pc.)

Part of this tutorial is about the cost effective use of pseudo curves.

Pseudo relative-permeability curves (and sometimes pseudo capillary-pressure curves) allow fine-grid layers, rows, and/or columns to be lumped into coarse grids WHILE MAINTAINING THE SAME FLUID-FLOWS AND PRESSURES AS THE FINE-GRID MODEL. The benefit is reduced runtime (and reduced study duration.)

Several authors have presented methods for calculating the desired pseudo curves. These range in simplicity from straight lines connecting endpoints to detailed calculations based on the flowing phases and pressure between the fine-grid blocks within each coarse-grid cell.

Some prefer to start with straight line and use their experience and judgement to make appropriate (end-point and curvature) modifications.

Others prefer to use software to back-calculate representative pseudo curves from fine-grid results. This is appealing because it holds the potential for saving considerable time and expense by predicting initial pseudo curves that work without modification.

Schlumberger - GeoQuest offers PSEUDO, a comprehensive utility package that back-calculates pseudo curves from fine-grid inter-block flows. It is possible that PSEUDO's curves are rate dependent.

The goal of this study is to test how well the pseudo curves produced by PSEUDO (Schlumberger - GeoQuest) work without using engineering judgement to modify them.

Ideally, the initial pseudo curves will model accurate coning performance for a well with a cylindrical, local-grid-refinement within a cartesian grid. Ideally, the initial pseudo curves will work equally well for a cartesian lgr with a cartesian grid.

This study finds that PSEUDO's pseudo curves (like all other pseudo curves I have used) require adjustment (based on engineering judgement) before it is possible to reproduce fine-grid rates and pressures with a coarse grid.

This study uses a 90 x 1 x 135 radial model and Eclipse' PSEUDO software to generate Kyte and Berry pseudo curves (including pseudo capillary-pressure curves) for 10 x 1 x 15 and for 3 x 1 x 5 models. The underlying data is from Weinstein, Chappalear & Nolan's data as presented in the Second SPE Comparative Study Project.

The Chappalear data is a 10-horizontal-layer (gas and water) coning problem. The porosities and permeabilities are homogeneous by layer. The layers are thickest in the aquifer and thinnest at the perforations. The ratio of thickest to thinnest is about 20-to-1, and the total thickness is 320 feet. The outer radius is about 2050 ft. The peak oil rate is 1,000 stbd.

Pseudo curves (can) reduce runtime without loss of accuracy.
- Pseudo curves are used with coarse simulation grids.
- The purpose of pseudo curves is to mimic fine-grid simulations.

There are several published methods for predicting pseudo-relative permeabilities.
- The simplest method uses straight lines between end points.
- The simpler methods are suitable for spreadsheet calculations.
- The more complicated methods require cell-to-cell flowrates.
- All of them seem have a strong empirical flavor.

Some empirical work successfully uses negative pseudo-relative permeabilities.
- Negative pseudo-relative permeabilities can work better than positive ones.
- The curves look odd.
- Odd looking curves bother some engineers and managers.

It appears (at best) that all the methods provide a starting point.
- There is plenty of opportunity to use engineering judgement:
  - To adjust end points, and
  - To adjust curvatures.

Normally this is an engineering-judgement process.
- Sometimes saturation end points are adjusted.
- Sometimes relative-permeability end points are adjusted.
- Sometimes the curvature of the relative permeability is adjusted.
- Sometimes the capillary-pressure end points are adjusted.
- Sometimes the displacement (entry) pressure is adjusted.
- Sometimes the capillary-pressure curvature is adjusted.

All the approaches appear to benefit from end-point scaling.

End-point scaling may be best know for controlling gas and water production at the perforations. This is typically done by specifying a set of (up to six) pseudo curves for the perforations. The six curves are for Krow, Krog, Krw, Krg, Pcow, and Pcgo versus saturation.

End-point scaling also applies to cell pseudo curves. The technique modifies:

- critical saturations,
- maximum relative permeabilities, and
- entry (or displacement) capillary pressures.

The intermediate values are adjusted with linear interpolation.

It is also possible to modify the curvature of the relative-permeability and the capillary-pressure curves.

Changing the exponents in the Corey equations is a straight-forward way to adjust relative-permeability curvature.

Changing the "lambda" value is a straight-forward way to adjust capillary-pressure curvature. (See WorkBench.)

GeoQuest (Schlumberger) offers software (called PSEUDO) that calculates the (initial) pseudo curves (including pseudo-capillary-pressure curves when appropriate.)

This tutorial documents the steps required to run PSEUDO.

Input comes from special files saved during a fine-grid simulation.
- Initialization files (*.INIT,)
- Restart files (*.X# # # #, etc.,) and
- Pseudo definition files (*.PDF.)

This tutorial uses PDF files in the interactive mode with graphics.
- PDF files may be used interactively without graphics, or in batch mode.

Pseudo restart files are *significantly larger* than non-pseudo restart files.
- Inter-block flows are saved for every cell at every report (TSTEP) time.

This tutorial uses un-unified, formatted restart files (* . X# # # #)
- PSEUDOS keyword defaults to un-unified, formatted restart files.
- Perhaps other combinations will also work:
  - Un-unified, unformatted restart files (*.F# # # #),
  - Unified, unformatted restart files (*.UNRST), and
  - Unified, formatted restart files (*.FUNRST).

Output files include:
- Work-space, (*.WS), and
- Pseudo table output, (*.PTO.)

Simulation input file:
- The*.PTO information becomes part of a coarse-grid *.DATA file (for Eclipse.)

Consider saving multiple versions of the output files until the pseudo curves are done.

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Pseudo-Curve Keywords Used in *.DATA (the ECLIPSE input file)

The following applies to the fine-grid ECLIPSE input file (*.DATA) used to create output for subsequent input to PSEUDO.

This tutorial does NOT use the following keywords (in the RUNSPEC section.)
- SAVE, UNIFOUT, and UNIFIN
  - They are NOT required.
  - They are seem to prevent PSEUDO from running.

Use the PSEUDOS keyword (in the GRID section) to create *.INIT and *.X#### files.
- The PSEUDOS keyword forces 'RESTART=3'
  - in the RPTSOL keyword in the SOLUTION section, and
  - in the RPTSCHED keyword in the SCHEDULE section.

Use the 'RESTART=#' option with the RPTSOL keyword in the SOLUTION section.
Use the 'RESTART=#' option with the RPTSCHED keyword in the SCHEDULE section.
- This tutorial uses 'RESTART=2'
- 'RESTART=1' and 'RESTART=3' should also work.

Use TSTEP (or DATE) keywords in the SCHEDULE section to specify report times.
- This specifies when the restart (*.X####) files are written.

1. Open an X-Win32 session on the desired Unix Workstation.
2. Change into the directory with the fine-grid ECLIPSE output (and PSEUDO input.)
3. Type @PSEUDO (or @pseudo.)
4. Select the desired version.
5. Select the memory size.
6. Avoid background (in order to run interactively.)
7. Select interactive, with graphics.

1
```
rel1200@sparc309-1:/home/g2/rel1200%
```

2
```
cd local/usr/ecl/99a_1/eclipse/data/pseudo
```

3
```
@pseudo
```

4
```
Please enter version (98a, 99a_1[default]) :

1) /usr/local/ecl/99a_1/pseudo/source/pseudo_080Mb.exe
2) /usr/local/ecl/99a_1/pseudo/source/pseudo_240Mb.exe
```

5
```
Choose an executable ( 1 - 2) [default is 1] :
```

6
```
Do you want to run a PDF in the background ? (y/n) [default n]:

No local config file exists.
Master configuration file copied to current directory.

 PSEUDO   Version 99A.   Week 9912. Build Number  106.
   Please choose type of run :
   0 : Non-interactive run
   1 : Interactive, no graphics
   2 : Interactive, with graphics
 :
```

7
```
2
```

```
GRANITE version number 97A
Drivers available from configuration file are:-
 Device   0 : 'NULL DRIVER   '(NO GRAPHICAL OUTPUT)
 Device   1 : 'HP LASERJET   ' LANDSCAPE
 Device   2 : 'HP LASERJET   ' PORTRAIT
 Device   3 : 'HP PAINTJET   ' LANDSCAPE
 Device   4 : 'HP DESKJET    ' HP Deskjet
 Device   5 : 'POSTSCRIPT    ' LANDSCAPE
 Device   6 : 'POSTSCRIPT    ' PORTRAIT
 Device   7 : 'POSTSCRIPT    ' (FOR TI OMNILASER)
 Device   8 : 'POSTSCRIPT    ' Seiko Colour PS (Landscape)
 Device   9 : 'POSTSCRIPT    ' Seiko Colour PS (Portrait)
 Device  10 : 'PAINTJET XL300' HP Paintjet XL300 (HP/GL 2)
 Device  11 : 'HP LASERJET 3 ' HP Laserjet
 Device  12 : 'HP LASERJET 3 ' HP Laserjet
 Device  13 : 'GENERIC       ' Designjet 750C 24 Inch
 Device  16 : 'HP 7550 8-PEN ' LANDSCAPE
 Device  17 : 'HP 7550 8-PEN ' PORTRAIT
 Device  18 : 'PAINTJET XL300' Designjet 650C A0
Please hit return to continue list
or input the required device number.
```

1. Type <cr> to continue the list.

```
Device  19 : 'HP 7440 8-PEN ' Landscape
Device  20 : 'HP 7596 8-PEN ' (DRAFTMASTER)
Device  40 : 'NULL DRIVER   ' with hardcopy
Device  41 : 'TEKTRONIX 41XX' colour TEKTRONIX
Device  42 : 'TEKTRONIX 41XX' colour TEKTRONIX (H.COPY)
Device  45 : 'TEKTRONIX 4510' (FROM ANY TERMINAL - VIA A FILE)
Device  51 : 'X-Windows     ' for Dec Alpha
Device  52 : 'X-Windows     ' for Sun (SunOS 4.1.3)
Device  53 : 'X-Windows     ' for Sun (Solaris 2)
Device  54 : 'X-Windows     ' for Silicon Graphics
Device  55 : 'X-Windows     ' for RS/6000
Device  56 : 'X-Windows     ' for hp700
Device  57 : 'X-Windows     ' for MacIntosh MacX
Device  58 : 'X-Windows     ' for PC/XVIEW
Device  70 : 'VERSATEC 3444 ' COLOUR VERSATEC
Device  71 : 'VERSATEC 2766 ' A4/A3 THERMAL TRANSFER PLOTTER
Device  72 : 'VERSATEC V80  ' 36 INCH COLOUR PLOTTER
```

```
58
```

2. Type 58 <cr> to select device 58 (X-Windows for PC/XVIEW)

Read the input data & define pseudo grid and wells.

```
ECLipse 100 Pseudos

0:PSEUDO GENERATION OPTIONS

 1 Read fine grid data
 7 Load or save workspace
 9 Change package settings
10 Exit

 : 1
Enter name of file
or RETURN for BASE
 : CHAP90135_E
CHAP90135_E.INIT exists
Pseudo version   9801 restart version   9901
Fine grid read successfully
Type return to continue
```

1. Type 1 <cr>
2. Type CHAP90135-E <cr>
3. Type <cr>

```
ECLipse 100 Pseudos

0:PSEUDO GENERATION OPTIONS

 2 Define pseudo grid and wells
 6 Reset session
 7 Load or save workspace
 9 Change package settings
10 Exit

 : 2_
```

4. Type 2 <cr>

Interactively define the coarse-grid dimensions


```
ECLipse 100 Pseudos

2:DEFINE PSEUDOS TO BE GENERATED

0 Return to primary menu
1 Read from data file
2 Define pseudo grid interactively

 : 2
Enter X dimension of coarse grid
or RETURN for 1
 : 10
Enter Z dimension of coarse grid
or RETURN for 1
 : 15
Directional relative permeabilities ?
or RETURN for YES
 : no
```

1. Type 2 <cr> to interactively define the coarse grid
2. Type 10 <cr> to pick 10, coarse, radial cells
3. Type 15 <cr> to pick 15, coarse, layers
4. Type no <cr> for Krx = Kry

Which fine-grid radial cells belong to each coarse-grid radial cell?


```
Enter pseudo grid dividing I-coordinates
 : 9
Pseudo cell   1 is from   1 to   9
 : 18
Pseudo cell   2 is from  10 to  18
 : 27
Pseudo cell   3 is from  19 to  27
 : 36
Pseudo cell   4 is from  28 to  36
 : 45
Pseudo cell   5 is from  37 to  45
 : 54
Pseudo cell   6 is from  46 to  54
 : 63
Pseudo cell   7 is from  55 to  63
 : 72_
Pseudo cell   8 is from  64 to  72
 : 81
Pseudo cell   9 is from  73 to  81
Pseudo cell  10 is from  82 to  90
```

1. Type 9 <cr> to set the 1st nine, fine, radial cells to be the 1st coarse, radial cell
2. Type 18 <cr> to se fine-grid radial cells 10 to 18 as the 2nd coarse-grid radial cell
3. Type 27 <cr>
4. Type 36 <cr>
5. Type 45 <cr>
6. Type 54 <cr>
7. Type 63 <cr>
8. Type 72 <cr>
9. Type 81 <cr> PSEUDO defines the final coarse-grid, radial cell as the remaining fine-grid, radial cells

Which fine-grid layers belong to each coarse-grid layer?

```
Enter pseudo grid dividing K-coordinates
 : 9
Pseudo cell   1 is from   1 to   9
 : 18
Pseudo cell   2 is from  10 to  18
 : 27
Pseudo cell   3 is from  19 to  27
 : 36
Pseudo cell   4 is from  28 to  36
 : 45
Pseudo cell   5 is from  37 to  45
 : 54
Pseudo cell   6 is from  46 to  54
 : 63
Pseudo cell   7 is from  55 to  63
 : 72
Pseudo cell   8 is from  64 to  72
 : 81_
Pseudo cell   9 is from  73 to  81
 : 90
Pseudo cell  10 is from  82 to  90
 : 99_
Pseudo cell  12 is from 100 to 108
 : 117
Pseudo cell  13 is from 109 to 117
 : 126
Pseudo cell  14 is from 118 to 126
Pseudo cell  15 is from 127 to 135
Enter list of well names
terminated with a blank
 : PRODUCER
 :
Number of active cells in pseudo grid is    150
Type return to continue
```

1. Type 9 <cr> to set the 1st nine, fine layers to be the 1st coarse layer
2. Type 18 <cr>
3. Type 27 <cr>
4. Type 36 <cr>
5. Type 45 <cr>
6. Type 54 <cr>
7. Type 63 <cr>
8. Type 72 <cr>

9. to 13. 81, 90, 99, 108, 117

15. Type 126 <cr> PSEUDO defines the final coarse layer as the remaining fine layers
16. Type PRODUCER <cr>
17. Type <cr> to finish identifying wells

Define which pseudo curves to define (with averaged critical values)


```
ECLipse 100 Pseudos

0:PSEUDO GENERATION OPTIONS

 3 Generate pseudos
 6 Reset session
 7 Load or save workspace
 9 Change package settings
10 Exit

 : 3
Enter name of file
or return for CHAP90135_E
 :
Both,OW or OG
pseudo oil relative permeabilities
or RETURN for Both
 : both
Add averaged critical values to tables
or return for No
 : yes
Enter number of first file to be loaded
or RETURN for first found
 :
Enter number of last file to be loaded
or RETURN for last in sequence
 : _
```

1. Type 3 <cr> to create the pseudo curves
2. Type <cr>
3. Type both <cr>
4. Type yes <cr>
5. Type <cr> to pick the first *.X#### file
6. Type <cr> to pick the last continuous *.X#### file

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Save a workspace (*.WS now that pseudo curves have been created)

1. PSEUDO reads 11 *.X#### files (CHAP90135_E.X0001 throughCHAP90135_E.X0011)

2. Type <cr> to continue

```
ECLipse 100 Pseudos

0:PSEUDO GENERATION OPTIONS

 4 Display/modify pseudos
 5 Apply monotonicity constraint
 6 Reset session
 7 Load or save workspace
 8 Output of generated data
 9 Change package settings
10 Exit

 : 7_
```

3. Type 7 <cr> to save the work done so far.

```
ECLipse 100 Pseudos

7:SAVE OR LOAD WORKSPACE

0 Return to primary menu
1 Load workspace
2 Save workspace
3 Change to formatted workspace
4 Save PDF file

 : 2
Enter name of file
or RETURN for CHAP90135_E
 :
CHAP90135_E.WS does not exist
Workspace saved sucessfully
Type return to continue
```

4. Type <cr> to save

5. Type <cr> to save as CHAP90135_E.WS

6. Type <cr> to continue

```
0 Return to primary menu
1 Load workspace
2 Save workspace
3 Change to formatted workspace
4 Save PDF file

 : 0_
```

7. There are no PDFs yet

8. Type 0 <cr> to return

9. It is wise to save a workspace when interrupted. It is then safe to exit PSEUDO.

Later, restart PSEUDO and load the desired workspace.

Save all the pseudo curves (*.PTO)

```
ECLipse 100 Pseudos

0:PSEUDO GENERATION OPTIONS

 4 Display/modify pseudos
 5 Apply monotonicity constraint
 6 Reset session
 7 Load or save workspace
 8 Output of generated data
 9 Change package settings
10 Exit

 : 8
Output of normalised pseudos
or RETURN for No
 :
Enter name of file
or RETURN for CHAP90135_E
 : CHAP90135_E.122
CHAP90135_E.122.PTO does not exist
Pseudo tables written successfully
Type return to continue
```

1. Type 8 <cr> to save all 122 sets of pseudo curves (Krw, Pcow, Krg, Pcgo, Krow, and Krog)
2. Type <cr> to save normalized curves
3. Type CHAP90135_E.122 <cr> to identify *.PTO as including all 122 sets of curves
4. Type <cr> to continue
5. *.PTO files cannot be reloaded. Fortunately the *.WS used to generate the *.PTO can be loaded.

Begin displaying pseudo curves by reviewing the index


```
ECLipse 100 Pseudos

0:PSEUDO GENERATION OPTIONS

 4 Display/modify pseudos
 5 Apply monotonicity constraint
 6 Reset session
 7 Load or save workspace
 8 Output of generated data
 9 Change package settings
10 Exit

 : 4_
```

1. Type 4 <cr>

```
ECLipse 100 Pseudos

4:DISPLAY OR MODIFY PSEUDOS

 0 Return to primary menu
 1 Index of pseudos
 2 Add to display group
 3 Remove from display group
 4 Clear display group
 5 Merge display group
 6 Replace display group
 7 Save as numbered set
 8 Apply monotonicity check to display group
 9 Plot
10 Supply curve
11 Perform batch commands

 : 1
All pseudos or Display group only ?
or RETURN for Display
 : all_
```

2. Type 1 <cr>

3. Type all <cr>

Index of pseudo curves

4.1:INDEX OF GENERATED PSEUDOS

Index	Cell or Well				Table	Type	Set	In DG?
1	1	1	1	-	122	Rock	0	N
2	2	1	1	-	122	Rock	0	N
3	3	1	1	-	122	Rock	0	N
4	4	1	1	-	122	Rock	0	N
5	5	1	1	-	122	Rock	0	N
6	6	1	1	-	122	Rock	0	N
7	7	1	1	-	122	Rock	0	N
8	8	1	1	-	122	Rock	0	N
9	9	1	1	-	122	Rock	0	N
10	10	1	1	-	122	Rock	0	N
11	1	1	2	-	1	Pseudo	0	N
12	2	1	2	-	2	Pseudo	0	N
13	3	1	2	-	3	Pseudo	0	N
14	4	1	2	-	4	Pseudo	0	N
15	5	1	2	-	5	Pseudo	0	N
16	6	1	2	-	6	Pseudo	0	N
17	7	1	2	-	7	Pseudo	0	N
18	8	1	2	-	8	Pseudo	0	N
19	9	1	2	-	9	Pseudo	0	N
20	10	1	2	-	10	Pseudo	0	N
21	1	1	3	-	11	Pseudo	0	N
22	2	1	3	-	12	Pseudo	0	N
23	3	1	3	-	13	Pseudo	0	N
24	4	1	3	-	14	Pseudo	0	N
25	5	1	3	-	15	Pseudo	0	N

Type C to continue, E to end

2. Type c <cr>

Index	Cell or Well	Table	Type	Set	In DG?
151	PRODUCER 1	120	Pseudo	0	N
152	PRODUCER 2	121	Pseudo	0	N

Type return to continue

3. Type <cr>

Each of the 150 coarse-grid cell has pseudo or rock curves. Also, the well is completed in two cells. Thus, there are 152 indices.

Each cell is identified by an index number.
Index = i + (j-1) *imax + (k-1) *imax *jmax.

31 cells have the original rock curves (instead of pseudo curves.) This is why there are only 122 table numbers.

The last index and table numbers are for the perforated cells and for the rock curve.

So far no curves have been assigned to sets.

So far no curves are in the display group.

It is up to the engineer to group similar pseudo curves into sets. The sets will (later) be converted into generalized pseudo curves.

The (reduced quantity of) generalized pseudo curves will be exported as a *.PTO file.

The *.PTO file provides the data needed to modify the Eclipse (*.DATA) input file.

This study uses PSEUDO to generate pseudo curves for two coarse-grid models (10x 1 x 15 and 3 x 1 x 5.)

Index of pseudo curves

WISDOM

It is easiest to manage the adjustment process when there is only one set of pseudo curves.

Multiple rock types may require multiple sets of pseudo curves.

Try to reduce the number of pseudo-curve sets by combining similar rock types.

Hypotheses about sets (for generalized pseudo curves)

Hopefully the grouped sets of similar pseudo curves (for the 10 x 1 x 15 coarse-grid model) will follow a logical pattern that represents the flow characteristics of the reservoir (model.)

Perhaps the perforated (completed) cells will be described by a single set of pseudo curves.

This coning example may have seven logical layers (based on initial conditions):

Gas cap,	90-k-Layers 1 to 6
Gas-cap transition zone (gas-oil capillary pressure,)	90-k-Layers 7 to 12
Oil zone above the perforations,	90-k-Layers 13 to 24
Oil zone in perforations,	90-k-Layers 25 to 36
Oil zone below perforations,	90-k-Layers 37 to 42
Oil transition zone (oil-water capillary pressure,) and	90-k-Layers 43 to 72
Aquifer	90-k-Layers 73 to 90

This probably simplifies to five logical layers when capillary pressures are negligible.

Cone growth will probably tilt the logical layers towards the perforations. This suggests the need for at least two radial versions of the generalized pseudo curves for each layer. The following table lists the radii for cells i = 1 through i = 10.

Radial cell # (i)	rw	1	2	3	4	5	6	7	8	9	10
Outer radii, ft	0.25	0.62	1.52	3.73	9.19	22.6	55.7	137	338	832	2050

A future cartesian grid might have horizontal-cell dimensions of 50 to 300 ft. It would be convenient of the generalized pseudo curves (in the radial direction) covered cells 1 to 6 and 7 to 10. Another convenient arrangement would be cells 1 to 5, 6 to 7, and 8 to 10.

There may be other complicating factors:

Gas-oil and oil-water contact movement may blur the pseudo curves through time.
The pseudo curves may be rate dependent.

This suggests the possibility of modeling the 90 x 1 x 135 fine grid with a very coarse grid.
Possibilities include: 3 x 1 x 7 3 x 1 x 5 2 x 1 x 7 2 x 1 x 5

This study tests pseudo curves for 3 x 1 x 5 and 10 x 1 x 15 models.

Add pseudo curves to the display group

```
ECLipse 100 Pseudos
________________________________________

4:DISPLAY OR MODIFY PSEUDOS

 0 Return to primary menu
 1 Index of pseudos
 2 Add to display group
 3 Remove from display group
 4 Clear display group
 5 Merge display group
 6 Replace display group
 7 Save as numbered set
 8 Apply monotonicity check to display group
 9 Plot
10 Supply curve
11 Perform batch commands



 : 2
Select by Index,Table,Cell,Box,Well or Set?
or RETURN for Cell
 : box
Enter box lower x-coordinate
or RETURN for     1
 : 1
Enter box upper x-coordinate
or RETURN for    10
 : 8
Enter box lower z-coordinate
or RETURN for     1
 : 2_
Enter box upper z-coordinate
or RETURN for    15
 : 2
Include rock curves?
or type RETURN for No
 : no
  8 pseudos added
Type return to continue
```

The previous discussion (confirmed by a significant amount of labor) hypothesized that generalized pseudo curves tend to follow layers.

This slide shows how to add adjacent coarse-grid cells to the current display group using the box option.

This box is for i = 1 to 10   j = 1   k = 2.

2. Type 2 <cr> to create the 1st set

3. Type box <cr>

4. Type 1 <cr> for i = 1

4. Type 8 <cr> for i = 10

5. Type 2 <cr> for k = 2

6. Type 2 <cr> for k = 2

7. Type <cr> exclude rock curves

8. Type box <cr>

Verify the display-group additions

```
ECLipse 100 Pseudos

4:DISPLAY OR MODIFY PSEUDOS

 0 Return to primary menu
 1 Index of pseudos
 2 Add to display group
 3 Remove from display group
 4 Clear display group
 5 Merge display group
 6 Replace display group
 7 Save as numbered set
 8 Apply monotonicity check to display group
 9 Plot
10 Supply curve
11 Perform batch commands

 : 1
All pseudos or Display group only ?
or RETURN for Display
 : _
```

2. Type 1 <cr>

3. Type <cr>

WISDOM

The wise engineer reviews the index of pseudos each time the display group is changed.

This compensates for the ease with which the index, cell, table, box, etc. options can add/deleted extra cells.

4. Verify the selection

Index	Cell or Well				Table	Type	Set	In DG?
11	1	1	2	-	1	Pseudo	0	Y
12	2	1	2	-	2	Pseudo	0	Y
13	3	1	2	-	3	Pseudo	0	Y
14	4	1	2	-	4	Pseudo	0	Y
15	5	1	2	-	5	Pseudo	0	Y
16	6	1	2	-	6	Pseudo	0	Y
17	7	1	2	-	7	Pseudo	0	Y
18	8	1	2	-	8	Pseudo	0	Y

Type return to continue

5. Type <cr>

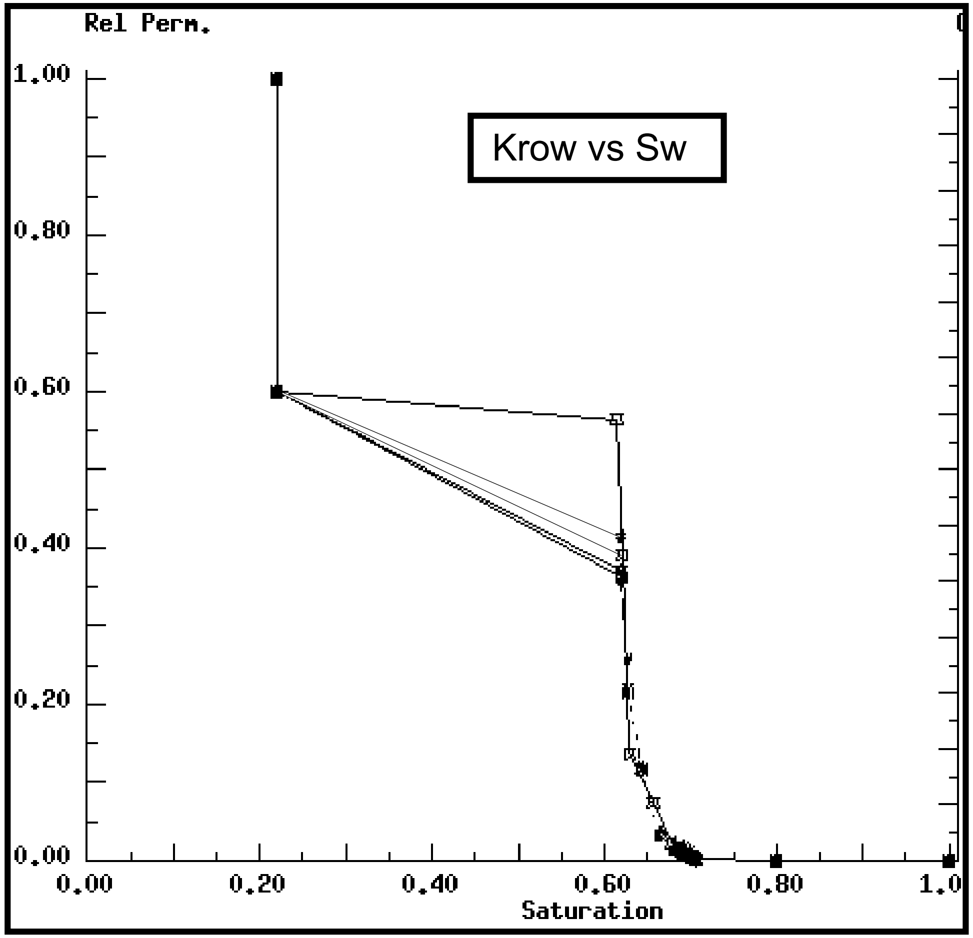
Plot Krow versus Sw (for all pseudo curves in the display group)

```
ECLipse 100 Pseudos

4:DISPLAY OR MODIFY PSEUDOS

 0 Return to primary menu
 1 Index of pseudos
 2 Add to display group
 3 Remove from display group
 4 Clear display group
 5 Merge display group
 6 Replace display group
 7 Save as numbered set
 8 Apply monotonicity check to display group
 9 Plot
10 Supply curve
11 Perform batch commands

 : 9
Plot All,Kr,Pc, or specify
KROW,KROG,KRW,PCW,KRG,PCG for single curves
 : krow
Device number
 : 58_
```

1. Type 9 <cr>

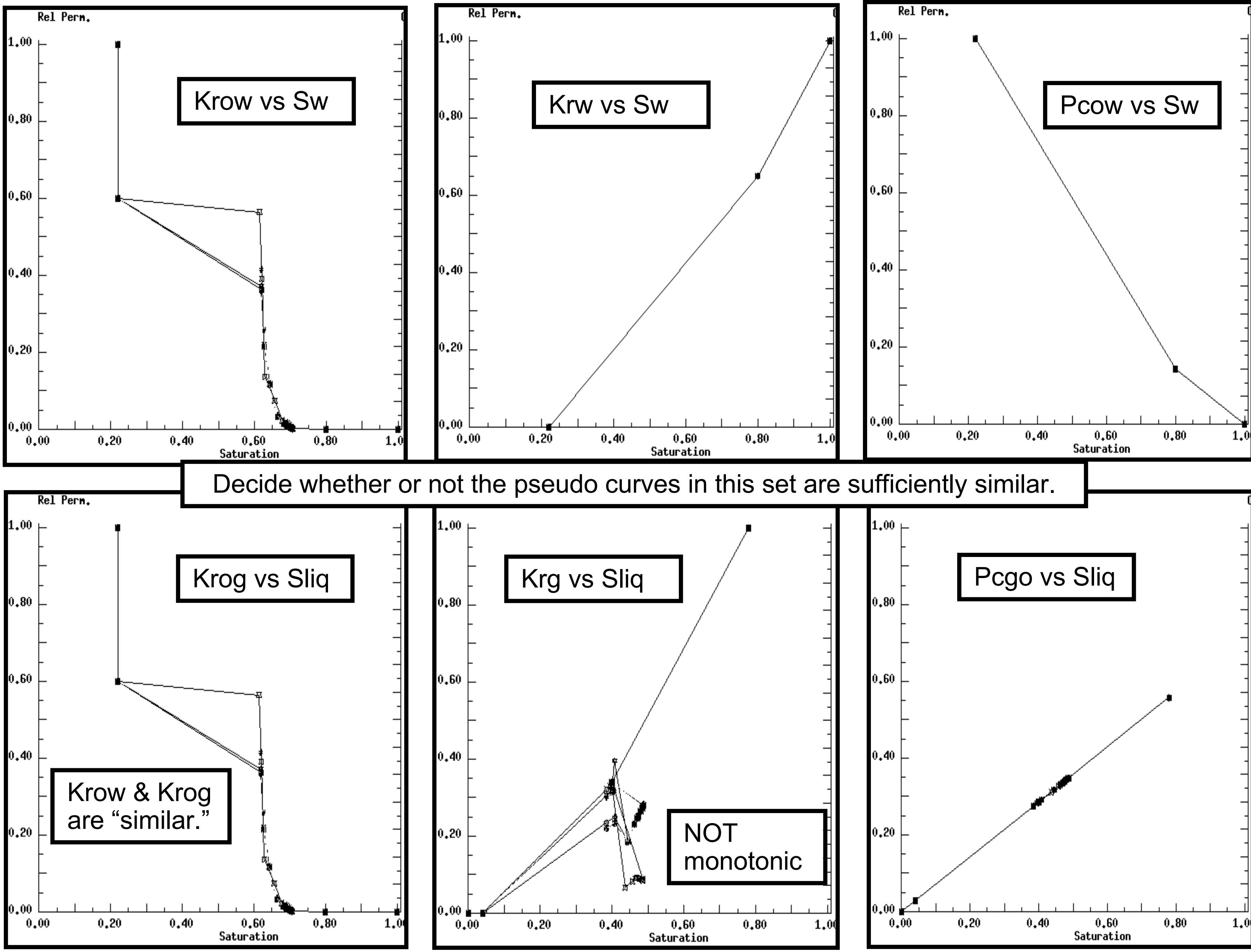
2. Type Krow <cr>

3. Type 58 <cr>



5. Type <cr>

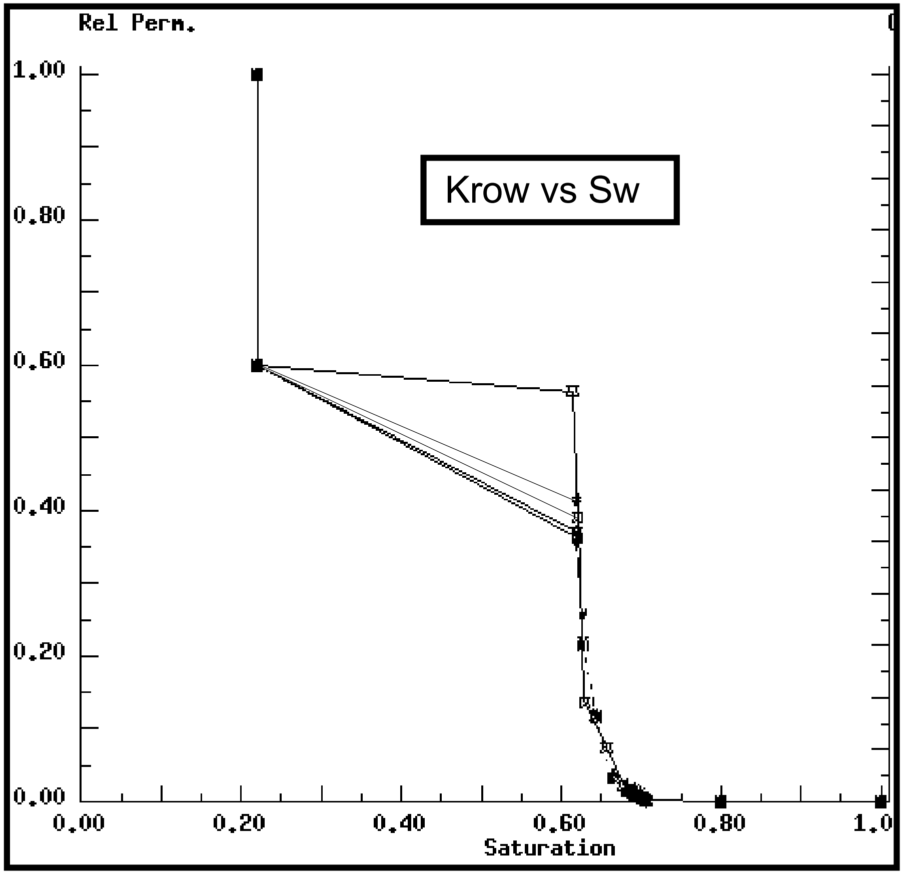
Compare (display group) plots of Krow, Krw, Pcow, Krog, Krg, Pcgo

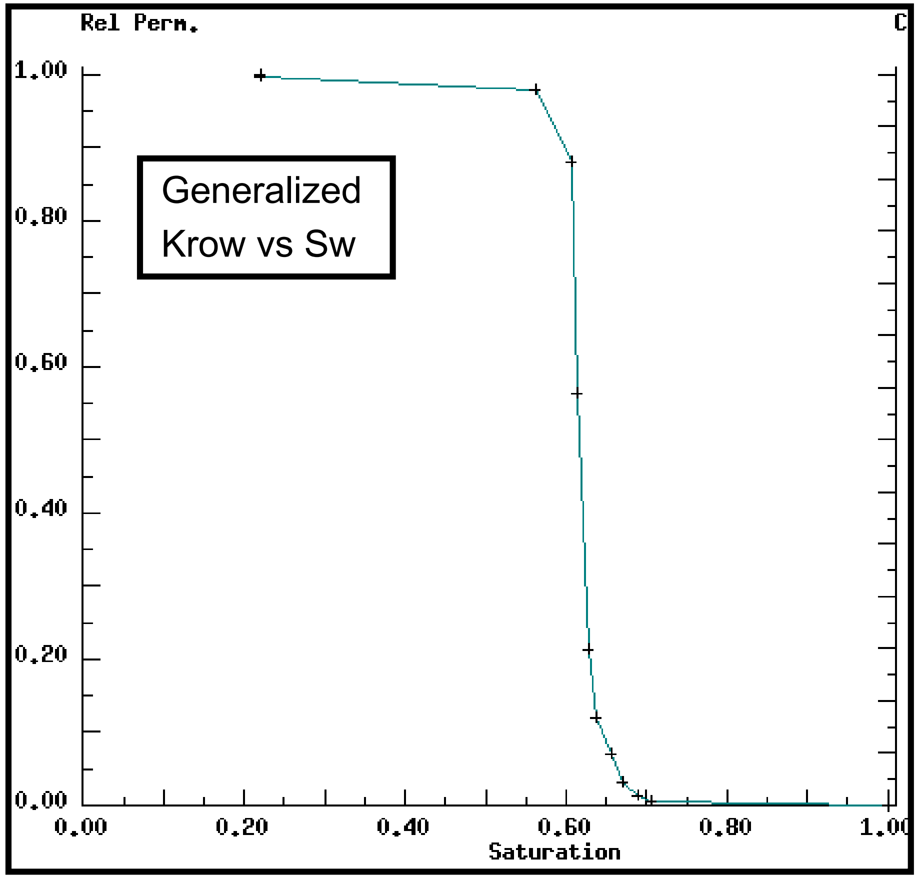


Decide whether or not the pseudo curves in this set are sufficiently similar.

Compare a display group with the manually generalized curve

Use engineering judgement to create a generalized pseudo curve that represents a selected set of similar pseudo curves.





Options 5, 6, 8, & 10 modify all the pseudo curves for all the cells in the display group.

Option 5 (Merge Display Group) automatically converts the curves in the display group into a single file. There is now one more set of pseudo curves. Option 5 seems to give good results over 90% of the time. CAUTION: There is NO UNDO for option 5.

Option 6 (Replace Display Group) replaces the entire, current, display group with a single set of pseudo curves. There are now fewer sets of pseudo curves. All new *.PTO files will include the merged curves and exclude the individual curves that were used to create the merged curve. CAUTION: There is NO UNDO for option 6.

Option 8 (Apply Monotonicity Check to Display Group) forces the curves in the display group to be monotonic (because Eclipse requires monotonic relative-permeability and capillary-pressure curves.) CAUTION: There is NO UNDO option 8 command. CAUTION: It appears that option 8 misses some non-monotonicity.

Option 10 (Supply Curve)
- gives the user more control,
- lets the user to manually merge similar pseudo curves,
- allows the user to skip options 5 and 8,
- should be plotted, verified, and edited BEFORE using as Eclipse input,
- is labor intensive.

I made 11 pseudo-curve sets for the 10 x 1 x 15 model with option 10.

11 curves = 9 pseudo + 1 original rock curve + 1 well-perforation.

See :\Laine \U_guides \Sim \Eclipse \BlackOil \Pseudo \10x15-11.xls.

SAVE A WORK SPACE FROM TIME TO TIME

WISDOM

The wise engineer frequently saves the workspace. This makes it possible to UNDO the undo-able (by exiting and restarting PSUEDO.) Merge, Monotonize, Replace, & Supply Curves cannot be undone.

The following example was made after merging (but before replacing) 10 display groups. Thus there were 132 (= 122 + 10) indices.

```
ECLipse 100 Pseudos

0:PSEUDO GENERATION OPTIONS

 4 Display/modify pseudos
 5 Apply monotonicity constraint
 6 Reset session
 7 Load or save workspace
 8 Output of generated data
 9 Change package settings
10 Exit

 : 7_
```

2. Type 7 <cr>

3. Type 2 <cr>

```
ECLipse 100 Pseudos

7:SAVE OR LOAD WORKSPACE

0 Return to primary menu
1 Load workspace
2 Save workspace
3 Change to formatted workspace
4 Save PDF file

 : 2
Enter name of file
or RETURN for CHAP90135_E.131
 : CHAP90135_E.132
CHAP90135_E.132.WS does not exist
Workspace saved sucessfully
Type return to continue
```

4. Type CHAP90135_E.132 <cr> to save the (in-progress version of the 132-table) *.WS file. Note: *.WS files are binary files.

5. Type 0 <cr>

SAVE A PSEUDO TABLE OUTPUT FROM TIME TO TIME

WISDOM

Remember to use option 6 (menu 4) to replace each display group with its respective merged (or supplied) curves BEFORE using menu 8 to create a *.PTO file. This would have replaced all 121 of the initial pseudo-curve sets with the 10 supplied (or merged) pseudo-curve sets. (Set 122 is the original rock curves.) This said, the *.PTO's root filename might have been CHAP90135_E.1015.11. This would have identified the source model (90x1x135) the coarse-grid (10x1x15) and the number of saturation tables (11) in the *.PTO file.

```
ECLipse 100 Pseudos

0:PSEUDO GENERATION OPTIONS

 4 Display/modify pseudos
 5 Apply monotonicity constraint
 6 Reset session
 7 Load or save workspace
 8 Output of generated data
 9 Change package settings
10 Exit

 : 8
Output of normalised pseudos
or RETURN for No
 : yes
Enter name of file
or RETURN for CHAP90135_E.132
 :
CHAP90135_E.132.PTO does not exist
Pseudo tables written successfully
Type return to continue
```

1. Type 8 <cr>
2. Type yes <cr>
3. Type <cr>
4. Type <cr>

WISDOM

This is "interruption" insurance for meetings and for the end of the day.

```
ECLipse 100 Pseudos

0:PSEUDO GENERATION OPTIONS

 4 Display/modify pseudos
 5 Apply monotonicity constraint
 6 Reset session
 7 Load or save workspace
 8 Output of generated data
 9 Change package settings
10 Exit

 : 10_
```

5. Type 10 <cr> to quit PSEUDO (for now)

The following table summarizes the pseudo-curve sets used to supply (manually merge) the generalized pseudo curves (Krow, Krw, & Pcow vs Sw plus Krog, Krg , & Pcgo vs. Sliq.)

Indices	i	j	15-layer-k	90-layer-k	Tables	Supplied, Set	Generalized
1 to 10	1 to 10	1	1	1 to 6	122	0	rock curves
11 to 19	1 to 9	1	2	7 to 12	1 to 9	1	1001
20	10	1	2		10	1	1001
cell 10,1,2 (a remote cell) was forced into set 1, in spite of poor Krow and Krog matches.							
21 to 28	1 to 8	1	3	13 to 18	11 to 18	2	1002
29 to 30	9 to 10	1	3		19 to 20	0	use rock curves
31 to 37	1 to 7	1	4	19 to 24	21 to 27	3	1003
38 to 40	8 to 10	1	4		28 to 30	4	1004
41 to 47	1 to 7	1	5	25 to 30	31 to 37	5	1005
48	8	1	5		38	5	1005
cell 8,1,5 (blurred by goc motion) forced into set 5, in spite of poor Krow & Krog matches.							
49 to 50	9 to 10	1	5		39 to 40	5	1005
51 to 53	1 to 3	1	6	31 to 36	41 to 43	6	1006
cells 1-3,1,5 (blurred by goc motion) are more like gas cap than oil zone.							
54 to 55	4 to 5	1	6		44 to 45	7	1007
cell 4-5,1,5 (blurred by goc motion) are more like oil zone than gas cap.							
56 to 60	6 to 10	1	6		46 to 50	8	1008
61	1	1	7	37 to 42	122	0	rock curve
62 to 70	2 to 10	1	7		51 to 59	8	1008
71 to 80	1 to 10	1	8	43 to 48	60 to 69	8	1008
81	1	1	9	49 to 54	70	6	1006
82 to 85	2 to 5	1	9		71 to 74	9	1009
86 to 90	6 to 10	1	9		75 to 79	8	1008
91 to 130	1 to 10	1	10 to 13	55 to 78	80 to 119	9	1009
131 to 150	1 to 10	1	14 to 15	79 to 90	122	0	rock curves

Layers one through three exhibit significantly different pseudo curves. These differences indicate that the gas-oil transition zone (layer 2) is unique. Similarly, the oil-water transition zone (layers 10 to 12) are significantly different than either the oil zone or the aquifer. It happens that layer 13 (the top of the aquifer) is more like the transition zone than the aquifer.

In conclusion, the evidence points to a 9-layer (rather than a 7- or a 5-layer) very-coarse-grid model.

The following table summarizes the pseudo-curve sets used to supply (manually merge) the generalized pseudo curves (Krow, Krog, Krw, Krg, Pcow, and Pcgo.)

Indices	well name	i	j	15-layer-k	90-layer-k	Tables	Set	Generalized
151	Producer	1	1	7	37 to 42	120	10	1010
152	Producer	1	1	8	43 to 48	121	10	1010

The manual-merge is an average of the two perforation curves. This may affect the gas production (which is known to be sensitive to grid resolution.)

None of the underlying curves were either merged nor monotonized. There are 10 more indices (1001 to 1020) representing the 10, generalized sets of pseudo curves.

Each of the 10 generalized pseudo curves was created using Options 5 and 6 (menu 4.)

WISDOM

There are no UNDO and no DELETE features for the generalized pseudo curves.

Generalized pseudo curves 1005 and 1007 were supplied with flaws.
 They cannot be modified.
 The cannot be deleted.

SOLUTION: 1007 was recreated as 1011.

SOLUTION: 1005 was manually edited in the *.PTO file.

Payout for generalized pseudo curves

It took about four days to analyze PSEUDO's output and to generalize the the pseudo curves. (Perhaps one day was for learning PSEUDO's operation and limitations.) This was a 3-day investment. Unfortunately, it might take another 3 to 7 days to adjust the pseudo curves to match the fine-grid output. Thus, each set of pseudo curves might require a 5 to 10-day investment.

The payback is time saved during the computer-simulation portion of the study.

How much time can be saved?

Big studies typically involve overnight runs. A common tactic is to size the model and computer to complete one run in under 16 hours. The computer runs from 4 p.m. to 8 a.m. This gives the engineer 8 a.m. to 4 p.m. to evaluate the results and plan the next run.

The next productivity step is two runs per day. This requires run times under four hours. This gives the engineer 7 a.m. to 10 a.m. to evaluate the results and plan the next run. This also gives the engineer 2 p.m. to 5 p.m. to evaluate the results and plan the next run.

Two daily 4-hr runs is a compressed schedule.

It is possible to make three (or more) daily runs. This requires small, simple models with runtimes of one hour or less. The limitation is the time required to evaluate results and plan the next run.

The following table (subjectively) summarizes the relationship between runtime & runs / day.

Runtime	< 0.25 hr	0.25-1 hr	1-4 hour	4-16 hour	>16 hour
Runs /day	>8	4-8	2-4	1-2	<1

This provides a basis for judging the payout of an investment in generalized pseudo curves.

A previous table suggests that a 75% runtime reduction (16 * 25% = 4 hrs /run) nominally doubles the number of daily runs.

The results of a previous runtime study (see CHAP_E.ppt) indicate runtime reductions of at least 75% occur when the number of cells is cut in half. It is easy to halve the number of cells by using generalized pseudo curves.

Naturally, pseudo-curve predictions must closely match the fine-grid (rock-curve) runs.

Major studies nominally require 100 runs for history matching.

- Study duration is heavily affected by several factors:
  - Quality of input data.
  - Quantity of input data already electronically formatted as input data.
  - Number of wells.
  - Number of years of production data.
  - Number of future-development scenarios.
  - Size of the report.
- Study duration might span 4 to 18 months.
- Cutting run time to 4 hours (from 16 hours) could save 50 days (about two months.)

If one set of grid-block pseudo curves adequately describes the entire field, and
if similar wells can share a modest number of well-perforation pseudo curves, and
if it only takes 10 days to validate the pseudo curve,
then there is a big (40-day) saving.

However, a 10-day coning study may include only 4 days of simulation. A 4-day investment in generalized pseudo curves would be unacceptable.

Herein lies the challenge. The challenge is to reduce the time required to develop generalized pseudo curves.

The goal is to complete the task in less than one day. This seems possible.

Merging similar pseudo curves.

Option 6 (Replace Display Group) replaces the display group with the index of the supplied curve (PROVIDED) the user is satisfied that the supplied curve is adequate.

Use Option 2 to put a set into the display group.

Use Option 2 to put the appropriate supplied curve (Option 19) into the display group.

Use Option 1 to verify that the correct tables are in the display group.

```
ECLipse 100 Pseudos

4:DISPLAY OR MODIFY PSEUDOS

 0 Return to primary menu
 1 Index of pseudos
 2 Add to display group
 3 Remove from display group
 4 Clear display group
 5 Merge display group
 6 Replace display group
 7 Save as numbered set
 8 Apply monotonicity check to display group
 9 Plot
10 Supply curve
11 Perform batch commands

 : 6
Enter index to replace display group
 : 1001_
```

5. Type 6 <cr>

6. Type 1001 <cr> (1001 is the index number of the supplied curve for set 1.

Verify the merge

```
ECLipse 100 Pseudos

4:DISPLAY OR MODIFY PSEUDOS

 0 Return to primary menu
 1 Index of pseudos
 2 Add to display group
 3 Remove from display group
 4 Clear display group
 5 Merge display group
 6 Replace display group
 7 Save as numbered set
 8 Apply monotonicity check to display group
 9 Plot
10 Supply curve
11 Perform batch commands

 : 1
All pseudos or Display group only ?
or RETURN for Display
 : _
```

1. Type 1 <cr>

2. Type <cr>

Note the new table number.
113 = 122(prev tot) -10(=set 1) +1(index 1001.)

4. Type <cr>

```
ECLipse 100 Pseudos

4.1:INDEX OF GENERATED PSEUDOS

Index  Cell or Well Table Type   Set          In DG?

  11     1  1  2  -  113  Merged  1            Y
  12     2  1  2  -  113  Merged  1            Y
  13     3  1  2  -  113  Merged  1            Y
  14     4  1  2  -  113  Merged  1            Y
  15     5  1  2  -  113  Merged  1            Y
  16     6  1  2  -  113  Merged  1            Y
  17     7  1  2  -  113  Merged  1            Y
  18     8  1  2  -  113  Merged  1            Y
  19     9  1  2  -  113  Merged  1            Y
  20    10  1  2  -  113  Merged  1            Y
1001                 113  Merged  0            Y
Type return to continue
```

SAVE A WORK SPACE FROM TIME TO TIME

```
ECLipse 100 Pseudos

0:PSEUDO GENERATION OPTIONS

 4 Display/modify pseudos
 5 Apply monotonicity constraint
 6 Reset session
 7 Load or save workspace
 8 Output of generated data
 9 Change package settings
10 Exit

 : 7_
```

2. Type 7 <cr>

WISDOM

The wise engineer frequently saves the workspace.

This makes it easier to UNDO the undo-able

- Merges cannot be undone.
- Monotone cannot be undone.
- Supplied curves cannot be undone.

```
ECLipse 100 Pseudos

7:SAVE OR LOAD WORKSPACE

0 Return to primary menu
1 Load workspace
2 Save workspace
3 Change to formatted workspace
4 Save PDF file

 : 2
Enter name of file
or RETURN for CHAP90135_E.132
 : CHAP90135_E.11
CHAP90135_E.11.WS does not exist
Workspace saved sucessfully
Type return to continue
```

3. Type 2 <cr>

4. Type CHAP90135_E.11 <cr> to save the (in-progress version of the 132-table) *.WS file

5. Type 0 <cr>

SAVE A PSEUDO TABLE OUTPUT FROM TIME TO TIME


```
ECLipse 100 Pseudos

0:PSEUDO GENERATION OPTIONS

 4 Display/modify pseudos
 5 Apply monotonicity constraint
 6 Reset session
 7 Load or save workspace
 8 Output of generated data
 9 Change package settings
10 Exit

 : 8
Output of normalised pseudos
or RETURN for No
 :
Enter name of file
or RETURN for CHAP90135_E.11
 :
CHAP90135_E.11.PTO does not exist
Pseudo tables written successfully
Type return to continue
```

1. Type 8 <cr>
2. Type <cr>
3. Type <cr>
4. Type <cr>
5. Type 10 <cr> to quit PSEUDO (for now)

```
ECLipse 100 Pseudos

0:PSEUDO GENERATION OPTIONS

 4 Display/modify pseudos
 5 Apply monotonicity constraint
 6 Reset session
 7 Load or save workspace
 8 Output of generated data
 9 Change package settings
10 Exit

 : 10_
```

See 10x15-11.xls for tabular and chart versions of the 11 sets of pseudo curves.

The 11 sets include:

- 1 set of original rock curves,
- 1 set of well-perforation pseudo curves.
- 9 sets of cell-block pseudo curves.

There are 11 saturation tables for:

- Krw and Pcow versus Sw. (Keyword = SWFN.)
- Krg and Pcgo versus Sliq. (Keyword = SGFN.)
- Krow and Krog versus Sw. (Keyword = SOF3.)

There is one SATNUM table that assigns pseudo-curve tables to grid cells.

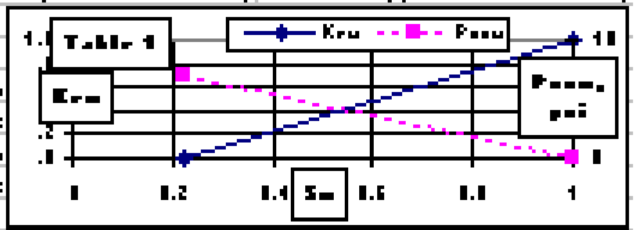
The COMPDAT keyword assigns well-perforation pseudo-curve tables.

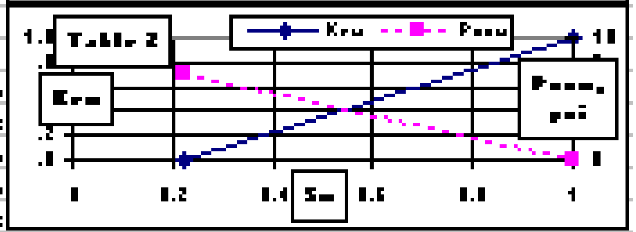
See 10x15-03.xls for tabular and chart versions of the three sets of pseudo curves.

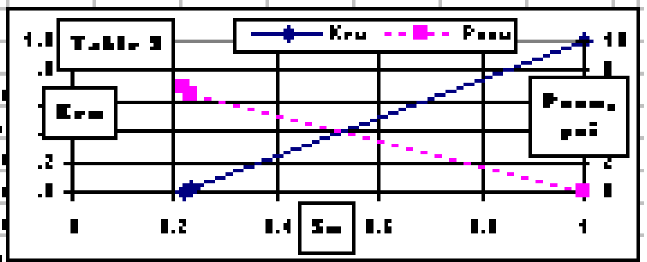
The 3 sets include:

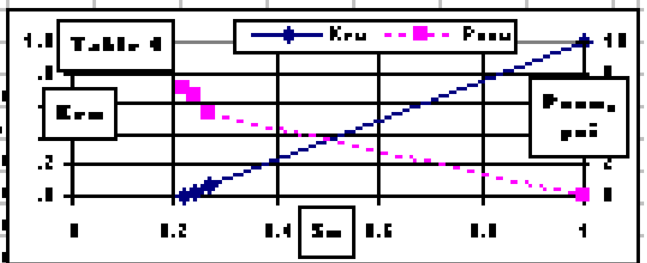
- 1 set of original rock curves,
- 1 set of well-perforation pseudo curves.
- 1 set of cell-block pseudo curves.

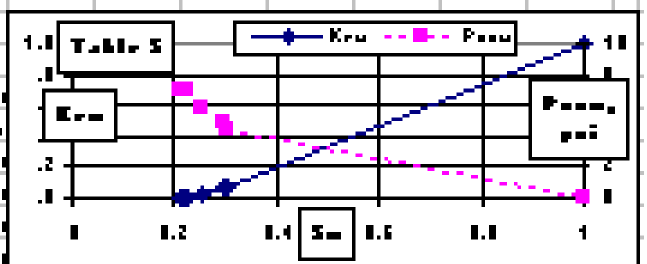
		11 pseudo Kr tables (for 10x1x15 grid) summarize CHAP 90 x 1 x 135 (fine-grid) simulation		
SWFN		Krw=Krw	TABLE 11 is for perforations (1x1x7 and 1x1x8)	Krow=Krog (NOT SURE WHY???)
Table 1	Table 1	1 (Merge)		
Sw	Sw	Krw	Pcow	
0.21947	0.21947	0.00364	7	Generated point
0.22	0.22	0.00364	7	Lowerend point
0.99739	0.99739	1	0.02546	Generated point
1	1	1	0	Upperend point
/	/			
Table 2	Table 2	2 (Merge)		
Sw	Sw	Krw	Pcow	
0.21947	0.21947	0	6.99	Generated point
0.22	0.22	0	6.99	Lowerend point
0.22183	0.22183	0.00116	6.9689	Generated point
0.99739	0.99739	1	0.02837	Generated point
1	1	1	0	Upperend point
/	/			
Table 3	Table 3	3 (Merge)		
Sw	Sw	Krw	Pcow	
0.21947	0.21947	0	7.00818	Generated point
0.22	0.22	0	7	Lowerend point
0.22183	0.22183	0.00364	6.91423	Generated point
0.23361	0.23361	0.0188	6.44447	Generated point
0.99739	0.99739	1	0.02546	Generated point
1	1	1	0	Upperend point
/	/			
Table 4	Table 4	4 (Merge)		
Sw	Sw	Krw	Pcow	
0.21947	0.21947	0	7.00817	Generated point
0.22	0.22	0	7	Lowerend point
0.22183	0.22183	0.00104	6.92764	Generated point
0.23597	0.23597	0.01928	6.44447	Generated point
0.26662	0.26662	0.0588	5.46252	Generated point
0.99739	0.99739	1	0.02546	Generated point
1	1	1	0	Upperend point
/	/			
Table 5	Table 5	5 (Merge)		
Sw	Sw	Krw	Pcow	
0.2124	0.2124	0	6.89908	Generated point
0.22	0.22	0	6.89908	Lowerend point
0.223	0.223	0.00261	6.89908	Generated point
0.25483	0.25483	0.02809	5.71711	Generated point
0.29255	0.29255	0.05819	4.8027	Generated point
0.30433	0.30433	0.074	4.51695	Generated point
0.99739	0.99739	1	0.02546	Generated point
1	1	1	0	Upperend point
/	/			
Table 6	Table 6	6 (Merge)		
Sw	Sw	Krw	Pcow	
0.21947	0.21947	0	6.98999	Generated point
0.22	0.22	0	6.98999	Lowerend point
0.22183	0.22183	0.02656	6.90072	Generated point
0.25719	0.25719	0.10466	5.5617	Generated point
0.27133	0.27133	0.12475	5.0261	Generated point

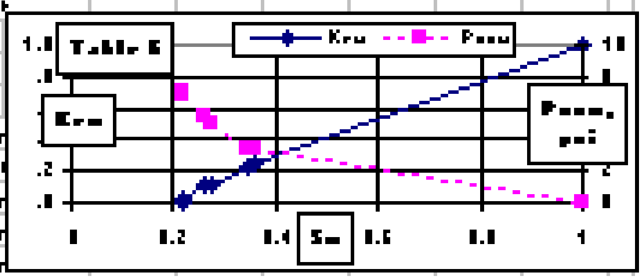












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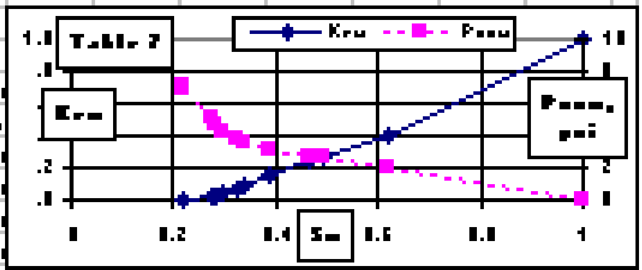
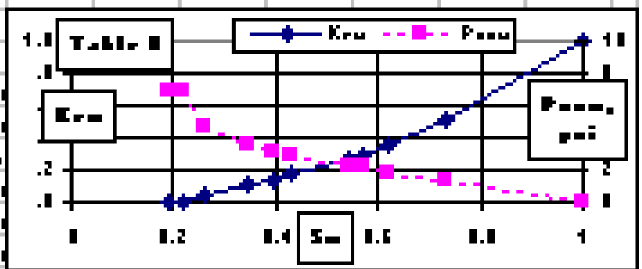
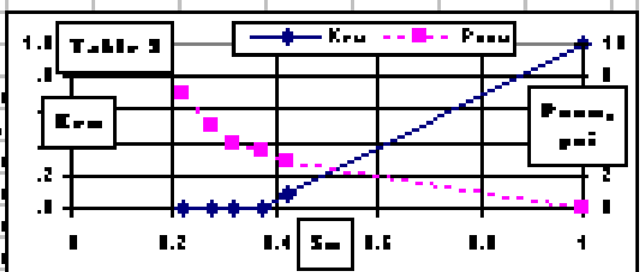
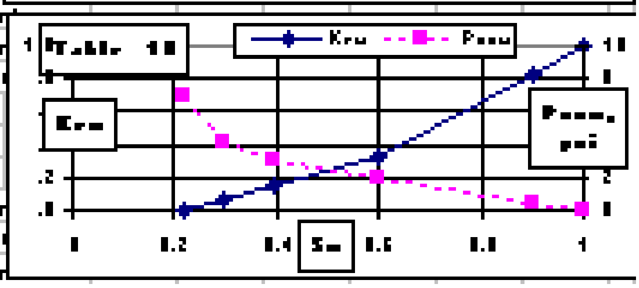
www.EricLaine.com

0.34205	0.34205	0.22517	3.46226	Generated point
0.35619	0.35619	0.24526	3.38874	Generated point
1	1	1	0	Upperend point
r	r			
Table 7	Table 7	7 (Merge	)	
Sw	Sw	Krw	Pcow	
0.21947	0.21947	0	7.00818	Generated poi
0.22	0.22	0	7	Lowerend poin
0.22183	0.22183	0.00364	6.92145	Generated poi
0.27369	0.27369	0.02442	5.01352	Generated poi
0.28076	0.28076	0.03164	4.75334	Generated poi
0.29255	0.29255	0.04366	4.17145	Generated poi
0.32083	0.32083	0.07253	3.75321	Generated point
0.33734	0.33734	0.08936	3.59959	Generated point
0.3892	0.3892	0.14915	3.11677	Generated point
0.46227	0.46227	0.2334	2.69853	Generated point
0.49056	0.49056	0.26601	2.55784	Generated point
0.61786	0.61786	0.40888	1.92475	Generated point
1	1	1	0	Upperend point
r	r			
Table 8	Table 8	8 (Merge	)	
Sw	Sw	Krw	Pcow	
0.18882	0.18882	0	6.78997	Generated poi
0.21947	0.21947	0	6.78997	Generated poi
0.22	0.22	0	6.78997	Lowerend poin
0.22183	0.22183	0.00364	6.78997	Generated poi
0.2619	0.2619	0.03539	4.69879	Generated poi
0.34441	0.34441	0.10078	3.58956	Generated poi
0.39391	0.39391	0.14	3.0804	Generated point
0.43163	0.43163	0.16989	2.87128	Generated point
0.54478	0.54478	0.26664	2.24393	Generated point
0.56835	0.56835	0.28679	2.12804	Generated point
0.61786	0.61786	0.34654	1.88467	Generated point
0.73101	0.73101	0.505	1.32841	Generated point
0.99739	0.99739	1	0.01886	Generated point
1	1	1	0	Upperend point
r	r			
Table 9	Table 9	9 (Merge	)	
Sw	Sw	Krw	Pcow	
0.21947	0.21947	0.00364	7	Generated poi
0.22	0.22	0.00364	7	Lowerend poin
0.22183	0.22183	0.00368	7	Generated poi
0.27369	0.27369	0.00457	4.98974	Generated poi
0.31612	0.31612	0.0053	4.00779	Generated poi
0.37034	0.37034	0.00624	3.45014	Generated poi
0.4222	0.4222	0.08852	2.91674	Generated poi
0.99739	0.99739	1	0.02546	Generated poi
1	1	1	0	Upperend point
r	r			
Table 10	Table 10	0 (Merge	)	
Sw	Sw	Krw	Pcow	
0.21947	0.21947	0.00364	7	Generated poi
0.22	0.22	0.00364	7	Lowerend point
0.22183	0.22183	0.00561	6.98999	Generated poi

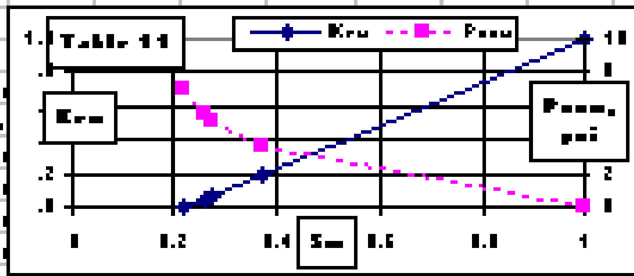


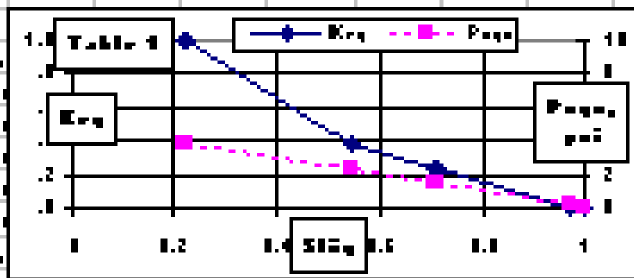


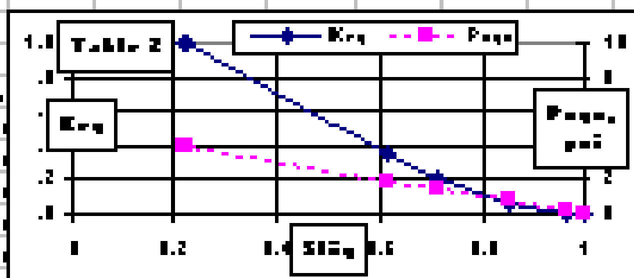


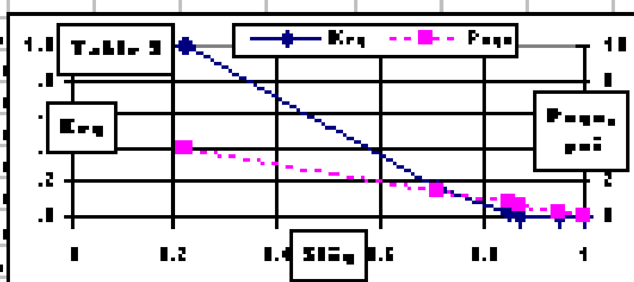


0.29726	0.29726	0.06879	4.02597	Generated point
0.39627	0.39627	0.15171	3.00766	Generated point
0.60136	0.60136	0.33355	1.9902	Generated point
0.89838	0.89838	0.82972	0.51664	Generated point
0.99739	0.99739	0.99464	0.02546	Generated point
1	1	1	0	Upperend point
/	/			
Table 11	Table 11	1 (Merge	)	
Su	Su	Kru	Pcou	
0.21947	0.21947	0	7.02636	Generated poi
0.22	0.22	0	7	Lowerend poin
0.22183	0.22183	0.00364	6.93627	Generated poi
0.25719	0.25719	0.05299	5.58485	Generated poi
0.27133	0.27133	0.07105	5.04429	Generated poi
0.37034	0.37034	0.19748	3.66229	Generated poi
0.99739	0.99739	0.99816	0.02546	Generated point
1	1	1	0	Upperend point
/				
SGFN				
Table 1	Table 1	1 (Merge	)	
Sg	Sliq	Krg	Pcgo	
0	1	0	0	Lowerend poin
0.02852	0.97148	0.00883	0.16698	Generated poi
0.29019	0.70981	0.22704	1.47605	Generated poi
0.29726	0.70274	0.23484	1.51143	Generated poi
0.4552	0.5448	0.38031	2.30158	Generated poi
0.77816	0.22184	0.99597	3.9	Generated poi
0.78	0.22	1	3.9	Upperend poin
/				
Table 2	Table 2	2 (Merge	)	
Sg	Sliq	Krg	Pcgo	
0	1	0	0	Lowerend poin
0.00259	0.99741	0.00405	0.04364	Generated poi
0.0356	0.9644	0.00985	0.2	Generated poi
0.15111	0.8489	0.06487	0.78532	Generated poi
0.28783	0.71217	0.20388	1.46814	Generated poi
0.38684	0.61316	0.34578	1.9626	Generated poi
0.77816	0.22184	1.00607	3.9	Generated point
0.78	0.22	1	3.9	Upperend point
/				
Table 3	Table 3	3 (Merge	)	
Sg	Sliq	Krg	Pcgo	
0	1	0	0	Lowerend poin
0.00259	0.99741	0.00376	0.02546	Generated poi
0.04974	0.95026	0.00624	0.26091	Generated poi
0.12989	0.87011	0.00883	0.66119	Generated poi
0.14639	0.85361	0.01663	0.74359	Generated poi
0.29019	0.70981	0.16989	1.46173	Generated poi
0.77816	0.22184	1.00147	3.89869	Generated poi
0.78	0.22	1	3.9	Upperend poin
/				
Table 4	Table 4	4 (Merge	)	
Sg	Sliq	Krg	Pcgo	
0	1	0	0	Lowerend point









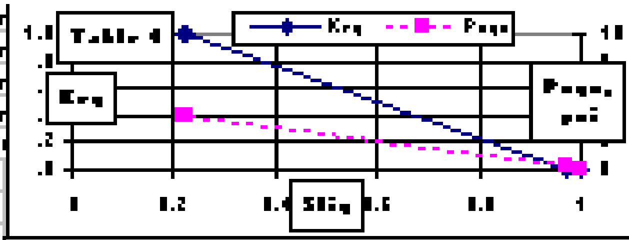
0.00259	0.99741	0.00126	0.02546	Generated poin	
0.02852	0.97148	0.00364	0.15596	Generated poin	
0.7758	0.2242	0.99803	3.9	Generated poin	
0.77816	0.22184	1.00117	3.9	Generated poin	
0.78	0.22	1	3.9	Upperend point	
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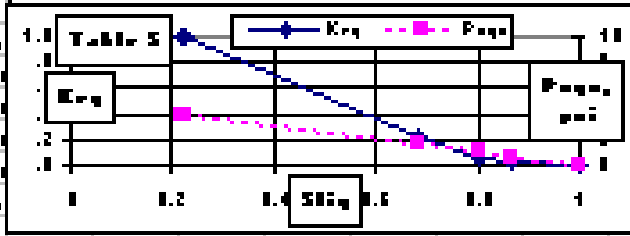
Table 5	Table 5	5 (Merge)			
Sg	Slig	Krg	Pcgo		
0	1	0	0	Lowerend poin	
0.13225	0.86775	0.02442	0.68582	Generated poin	
0.20061	0.79939	0.06598	1.02779	Generated poin	
0.31612	0.68388	0.22185	1.60561	Generated poin	
0.77816	0.22184	0.99721	3.9	Generated poin	
0.78	0.22	1	3.9	Upperend poin	
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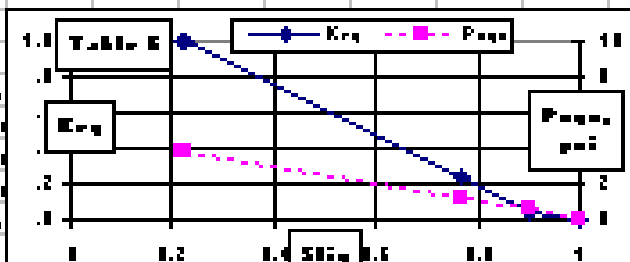
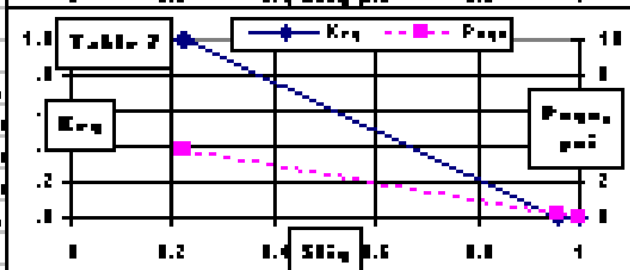
Table 6	Table 6	6 (Merge)			
Sg	Slig	Krg	Pcgo		
0	1	0	0	Lowerend poin	
0.09689	0.90311	0.04999	0.50748	Generated poin	
0.23126	0.76875	0.24526	1.1776	Generated poin	
0.77816	0.22184	0.99508	3.9	Generated poin	
0.78	0.22	1	3.9	Upperend poin	
/					
Table 7	Table 7	7 (Merge)			
Sg	Slig	Krg	Pcgo		
0	1	0	0	Lowerend poin	
0.00259	0.99741	0.00377	0.02546	Generated poin	
0.04503	0.95498	0.00624	0.23836	Generated poin	
0.77816	0.22184	1.00377	3.9	Generated poin	
0.78	0.22	1	3.9	Upperend poin	
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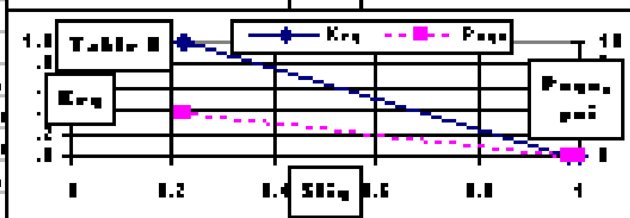
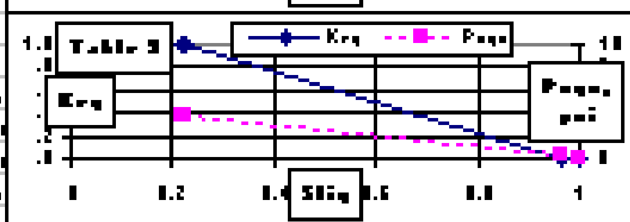
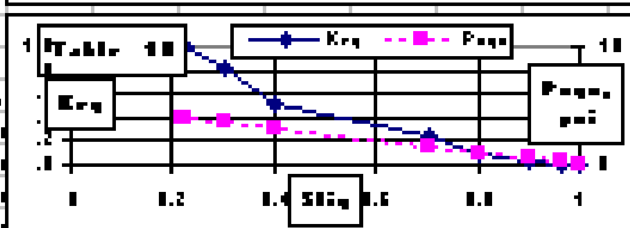
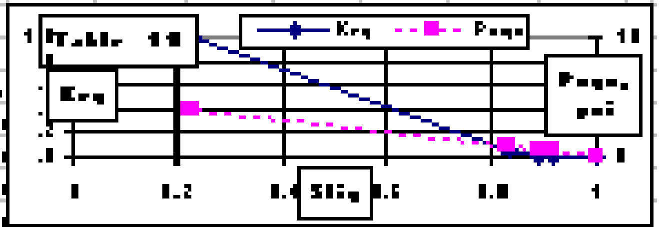
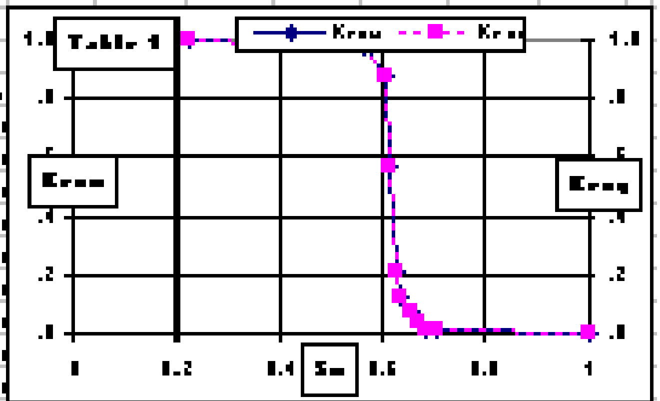
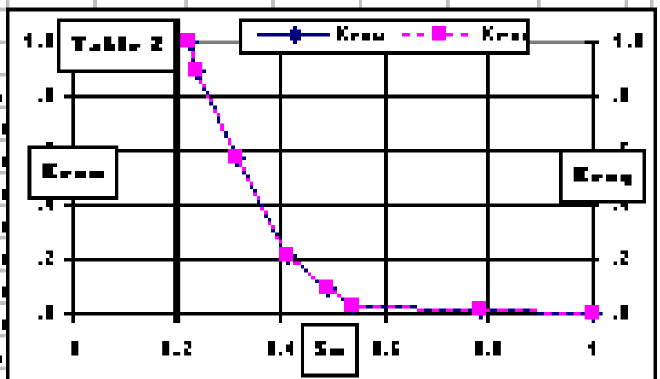
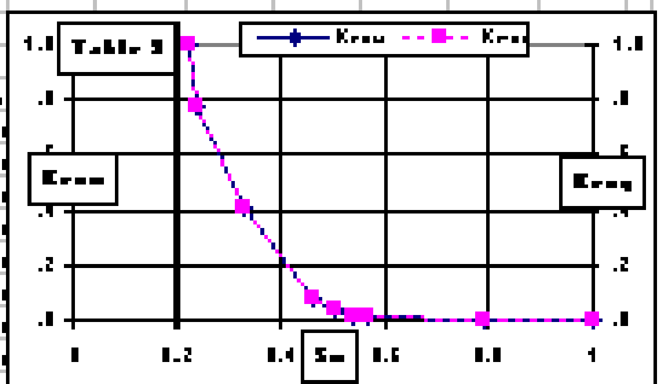
Table 8	Table 8	8 (Merge)			
Sg	Slig	Krg	Pcgo		
0	1	0	0	Lowerend poin	
0.02145	0.97855	0.00364	0.1139	Generated poin	
0.77816	0.22184	1.00117	3.9	Generated poin	
0.78	0.22	1	3.9	Upperend poin	
/					
Table 9	Table 9	9 (Merge)			
Sg	Slig	Krg	Pcgo		
0	1	0	0	Lowerend poin	
0.03324	0.96676	0.00883	0.2	Generated poin	
0.77816	0.22184	1.00117	3.9	Generated poin	
0.78	0.22	1	3.9	Upperend poin	
/					
Table 10	Table 10	0 (Merge)			
Sg	Slig	Krg	Pcgo		
0	1	0	0	Lowerend poin	
0.00259	0.99741	0.00123	0.02546	Generated poin	
0.03324	0.96676	0.00364	0.1785	Generated poin	
0.1016	0.8984	0.02442	0.51991	Generated poin	
0.19825	0.80175	0.10235	1.00259	Generated poin	
0.29726	0.70274	0.23743	1.49705	Generated point	
0.59664	0.40336	0.5024	2.99218	Generated point	

0.70036	0.29964	0.81413	3.51018	Generated point
0.77816	0.22184	1.00117	3.89868	Generated point
0.78	0.22	1	3.9	Upperend point
/				
Table 11	Table 11	1 (Merge)		
Sg	Slig	Krg	Pcgo	
0	1	0	0	Lowerend poin
0.0851	0.9149	0.00364	0.46618	Generated poi
0.11575	0.88426	0.00883	0.61876	Generated poi
0.16761	0.83239	0.0504	0.87697	Generated poi
0.77816	0.22184	1.00117	3.9	Generated poi
0.78	0.22	1	3.9	Upperend point
/				
SOF3				
Table 1	Table 1	1 (Merge)		
So	Sw	Krow	Krog	
0	1	0	0	Lowerend poin
0.29492	0.70508	0.00624	0.00624	Generated poi
0.31142	0.68858	0.01403	0.01403	Generated poi
0.33028	0.66972	0.03221	0.03221	Generated poi
0.34443	0.65558	0.07118	0.07118	Generated poi
0.36328	0.63672	0.12054	0.12054	Generated poi
0.37271	0.62729	0.21405	0.21405	Generated poi
0.38686	0.61314	0.56475	0.56475	Generated poi
0.39393	0.60607	0.88167	0.88167	Generated poi
0.43872	0.56128	0.98039	0.98039	Generated poi
0.78	0.22	1	1	Upperend point
/				
Table 2	Table 2	2 (Merge)		
So	Sw	Krow	Krog	
0	1	0	0	Lowerend poin
0.00261	0.99739	0.00405	0.00405	Generated poi
0.21006	0.78994	0.00985	0.00985	Generated poi
0.45994	0.54007	0.03301	0.03301	Generated poi
0.5118	0.4882	0.09673	0.09673	Generated poi
0.58959	0.41041	0.21257	0.21257	Generated poi
0.69095	0.30905	0.57167	0.57167	Generated poi
0.76403	0.23597	0.89023	0.89023	Generated poi
0.78	0.22	1	1	Upperend poin
/				
Table 3	Table 3	3 (Merge)		
So	Sw	Krow	Krog	
0	1	0	0	Lowerend poin
0.00261	0.99739	0.00364	0.00364	Generated poi
0.2077	0.7923	0.00624	0.00624	Generated poi
0.42929	0.57071	0.01143	0.01143	Generated poi
0.46229	0.53771	0.01922	0.01922	Generated poi
0.49294	0.50706	0.03741	0.03741	Generated poi
0.54008	0.45992	0.08157	0.08157	Generated poi
0.67445	0.32555	0.41148	0.41148	Generated poi
0.76639	0.23361	0.77257	0.77257	Generated poi
0.78	0.22	1	1	Upperend point
/				
Table 4	Table 4	4 (Merge)		









10x15-11.xls - 11 sets of Pseudo Curves (6 of 7.)

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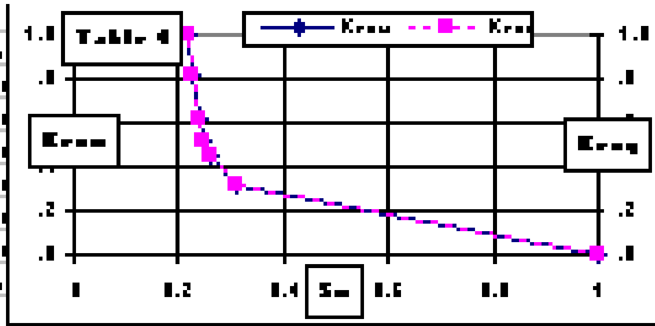
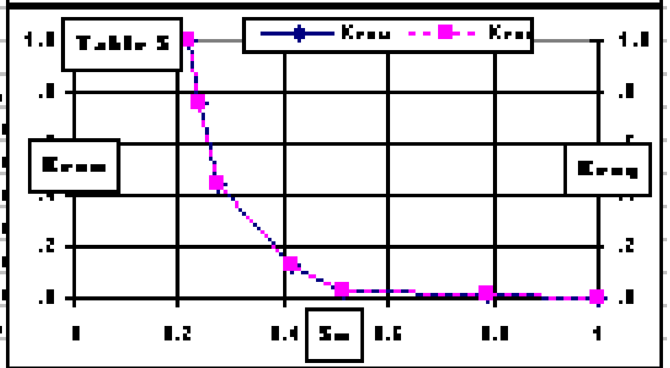
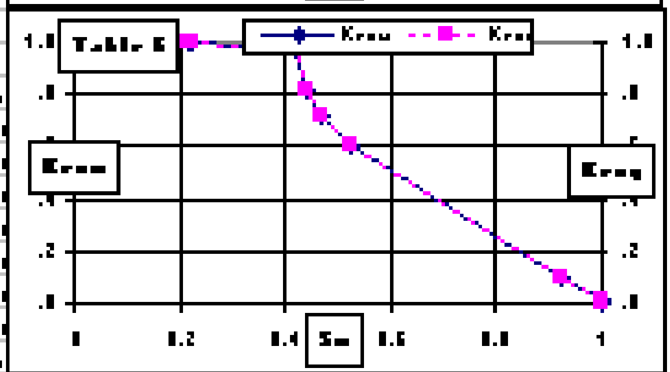
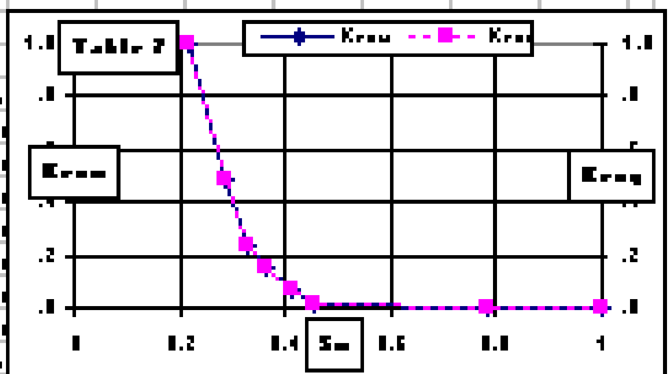
www.EricLaine.com

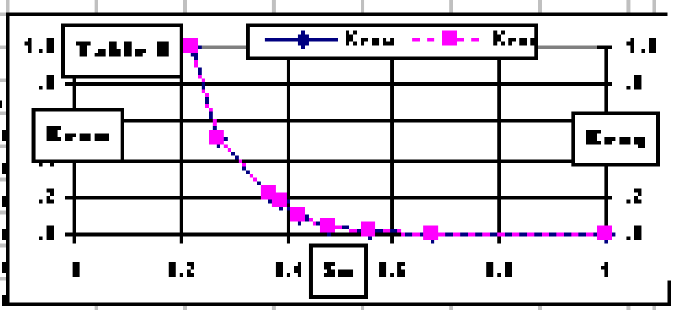
So	Sw	Krow	Krog	
0	1	0	0	Lowerend poin
0.6886	0.3114	0.32056	0.32056	Generated poi
0.7381	0.2619	0.44785	0.44785	Generated poi
0.7546	0.2454	0.52059	0.52059	Generated poi
0.76167	0.23833	0.61411	0.61411	Generated poi
0.77346	0.22654	0.82452	0.82452	Generated poi
0.77818	0.22183	1.00117	1.00117	Generated poi
0.78	0.22	1	1	Upperend poin
/				
Table 5	Table 5	5 (Merge)		
So	Sw	Krow	Krog	
0	1	0	0	Lowerend poin
0.00261	0.99739	0.00624	0.00624	Generated poi
0.21477	0.78523	0.00883	0.00883	Generated poi
0.48351	0.51649	0.02182	0.02182	Generated poi
0.58723	0.41277	0.13352	0.13352	Generated poi
0.72396	0.27604	0.43746	0.43746	Generated poi
0.75932	0.24068	0.75698	0.75698	Generated poi
0.78	0.22	1	1	Upperend poin
/				
Table 6	Table 6	6 (Merge)		
So	Sw	Krow	Krog	
0	1	0	0	Lowerend poin
0.00261	0.99739	0.01875	0.01875	Generated poi
0.07569	0.92431	0.09685	0.09685	Generated poi
0.47879	0.52121	0.60455	0.60455	Generated poi
0.5283	0.4717	0.72171	0.72171	Generated poi
0.55659	0.44342	0.81543	0.81543	Generated poi
0.58016	0.41984	0.97165	0.97165	Generated poi
0.77818	0.22183	1.00289	1.00289	Generated poi
0.78	0.22	1	1	Upperend poin
/				
Table 7	Table 7	7 (Merge)		
So	Sw	Krow	Krog	
0	1	0	0	Lowerend poin
0.00261	0.99739	0.00364	0.00364	Generated poi
0.21477	0.78523	0.00624	0.00624	Generated poi
0.5448	0.4552	0.01143	0.01143	Generated poi
0.58959	0.41041	0.06339	0.06339	Generated poi
0.63909	0.36091	0.14911	0.14911	Generated poi
0.66974	0.33026	0.23484	0.23484	Generated poi
0.70981	0.29019	0.48422	0.48422	Generated poi
0.78	0.22	1	1	Upperend poin
/				
Table 8	Table 8	8 (Merge)		
So	Sw	Krow	Krog	
0	1	0	0	Lowerend poin
0.00261	0.99739	0.00624	0.00624	Generated poi
0.32792	0.67208	0.00883	0.00883	Generated poi
0.44108	0.55892	0.01403	0.01403	Generated poi
0.51887	0.48113	0.0452	0.0452	Generated poi
0.57309	0.42691	0.09975	0.09975	Generated poi
0.61316	0.38684	0.16989	0.16989	Generated poi











0.63202	0.36798	0.21925	0.21925	Generated point
0.72631	0.27369	0.5102	0.5102	Generated point
0.78	0.22	1	1	Upperend point
/				
Table 9	Table 9	9 (Merge)		
Sa	Su	Krou	Krog	
0	1	0	0	Lowerend poin
0.00261	0.99739	0.00104	0.00104	Generated poi
0.67917	0.32083	0.00364	0.00364	Generated poi
0.78	0.22	1	1	Upperend poin
/				

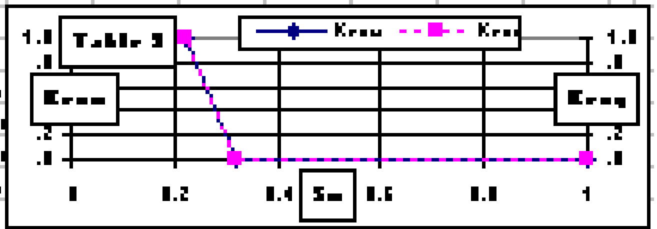


Table 10	Table 10	0 (Merge)		
Sa	Su	Krou	Krog	
0	1	0	0	Lowerend poin
0.00261	0.99739	0.00364	0.00364	Generated poi
0.401	0.599	0.00624	0.00624	Generated poi
0.60373	0.39627	0.12573	0.12573	Generated poi
0.70038	0.29962	0.39849	0.39849	Generated poi
0.78	0.22	1	1	Upperend point
/				

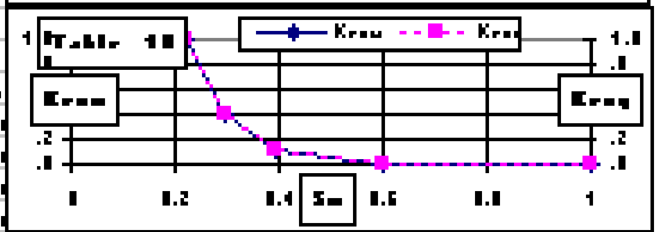
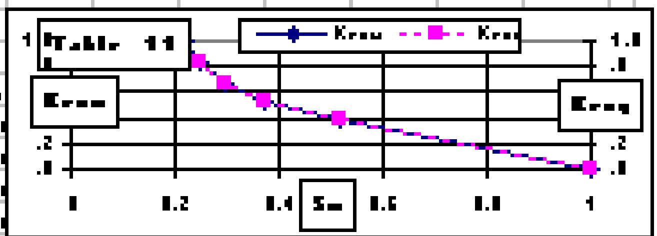


Table 11	Table 11	1 (Merge)		
Sa	Su	Krou	Krog	
0	1	0	0	Lowerend poin
0.48115	0.51885	0.38031	0.38031	Generated poi
0.62966	0.37034	0.51799	0.51799	Generated poi
0.7051	0.2949	0.66346	0.66346	Generated poi
0.74989	0.25011	0.83491	0.83491	Generated poi
0.78	0.22	1	1	Upperend point
/				
/				



REGIONS	======	======	======	======	======	======	======	======	======	======	======
SATNUM											
10	10	10	10	10	10	10	10	10	10	1	1
1	1	1	1	1	1	1	1	2	2	2	2
2	2	2	2	10	10	3	3	3	3	3	3
3	4	4	4	5	5	5	5	5	5	5	5
5	5	6	6	6	11	11	7	7	7	7	7
10	7	7	7	7	7	7	7	7	7	7	7
7	7	7	7	7	7	7	7	6	8	8	8
8	7	7	7	7	7	8	8	8	8	8	8
8	8	8	8	8	8	8	8	8	8	8	8
8	8	8	8	8	8	8	8	8	8	8	8
8	8	8	8	8	8	8	8	8	8	10	10
10	10	10	10	10	10	10	10	10	10	10	10
10	10	10	10	10	10	10					
/											

TABLE 11 is for perforations (1x1x7 and 1x1x8)

Krw & Pcow

3 sets of pseudo curves (for 10 x 1 x 15, coarse-grid) summarize CHAP 90 x 1 x 135 (fine-grid) simulation
Krow=Krog (NOT SURE WHY???)
Krx=Kry

SWFN

Table 1 rock curves

Sw	Sw	Krw	Pcow	
0.22	0.22	0	7	Lower end point
0.3	0.3	0.07	4	Rock curve point
0.4	0.4	0.15	3	Rock curve point
0.5	0.5	0.24	2.5	Rock curve point
0.6	0.6	0.33	2	Rock curve point
0.8	0.8	0.65	1	Upper critical point
0.9	0.9	0.83	0.5	Rock curve point
1	1	1	0	Upper end point

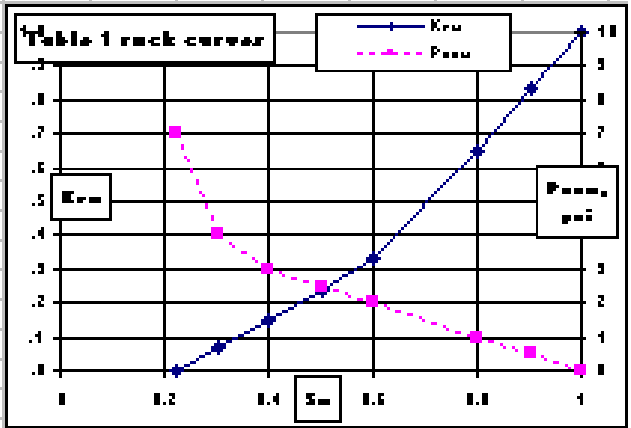
Table 2 cell pseudo curves

Sw	Sw	Krw	Pcow	
0.22	0.22	0	7	Lower end point
0.3983	0.3983	0.1615	3.0494	Generated point
0.4076	0.4076	0.1891	2.9732	Generated point
0.4342	0.4342	0.201	2.8334	Generated point
0.4588	0.4588	0.2473	2.7099	Generated point
0.4991	0.4991	0.272	2.5051	Generated point
0.5337	0.5337	0.4178	2.332	Generated point
0.6136	0.6136	0.4568	1.9322	Generated point
0.9086	0.9086	0.65	0.457	Generated point
1	1	1	0	Upper end point

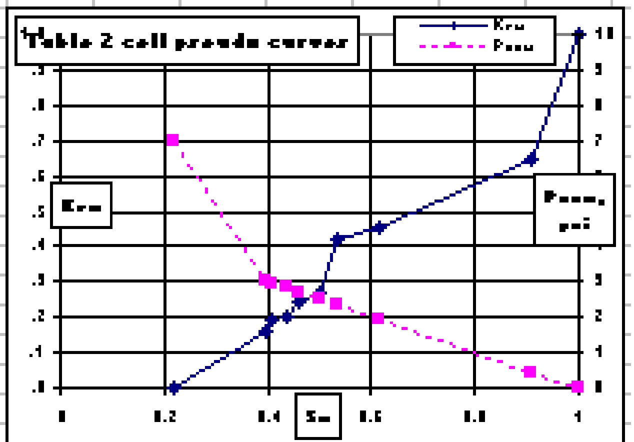
Table 3, well-perf pseudo curves

Sw	Sw	Krw	Pcow	
0.22	0.22	0	7	Lower end point
1	1	1	0	Upper end point
/	/			

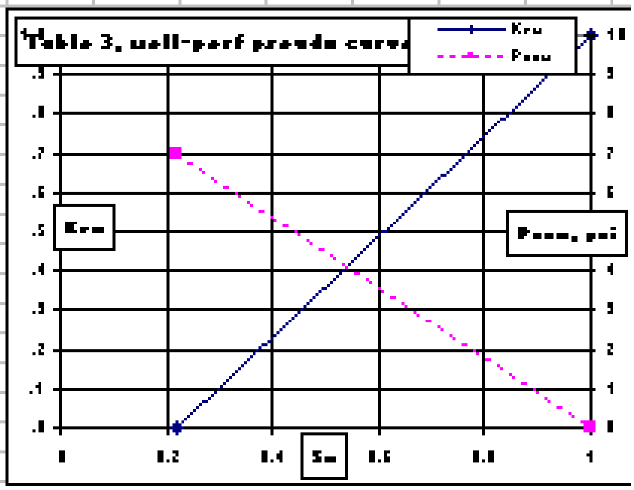
Font



Original Rock Curves



Cell-Block Pseudo Curves



Well-Perf Pseudo Curves

Krg & Pcgo

SGFN

Table 1 rock curves

Sg	Sliq	Krg	Pcgo	
0	1	0	0	Lower end point
0.04	0.96	0	0.2	Lower critical point
0.1	0.9	0.022	0.5	Rock curve point
0.2	0.8	0.1	1	Rock curve point
0.3	0.7	0.24	1.5	Rock curve point
0.4	0.6	0.34	2	Upper critical point
0.5	0.5	0.42	2.5	Rock curve point
0.6	0.4	0.5	3	Rock curve point
0.7	0.3	0.8125	3.5	Rock curve point
0.78	0.22	1	3.9	Upper end point

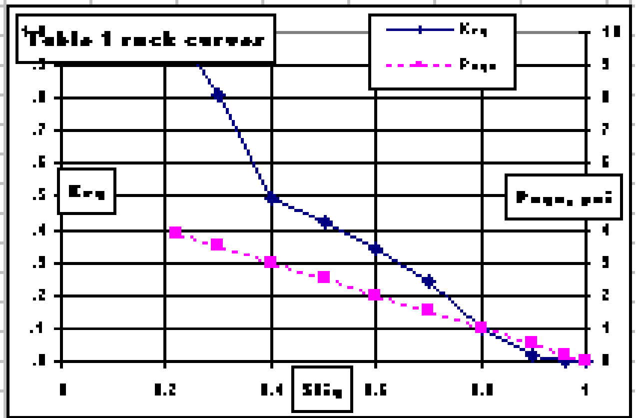


Table 2 cell pseudo curves

Sg	Sliq	Krg	Pcgo	
0	1	0	0	Lower end point
0.0025	0.9975	3E-05	0.0125	Generated point
0.011	0.989	0.0001	0.0549	Generated point
0.0188	0.9812	0.0009	0.0938	Generated point
0.0262	0.9738	0.0047	0.1308	Generated point
0.0345	0.9655	0.0073	0.1724	Generated point
0.0489	0.9511	0.0017	0.2444	Generated point
0.0993	0.9007	0.0126	0.4964	Generated point
0.1335	0.8665	0.014	0.6672	Generated point
0.145	0.855	0.063	0.7246	Generated point
0.1635	0.8365	0.0692	0.8179	Generated point
0.1728	0.8272	0.1339	0.8647	Generated point
0.2093	0.7907	0.1907	1.0464	Generated point
0.2471	0.7529	0.2917	1.2354	Generated point
0.3155	0.6845	0.4268	1.5774	Generated point
0.78	0.22	1	3.9	Upper end point

/

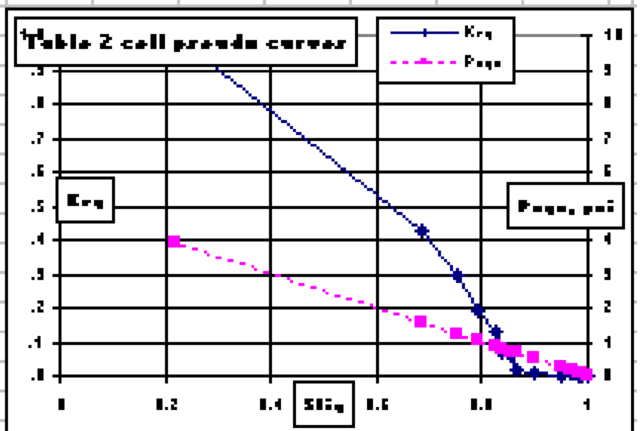
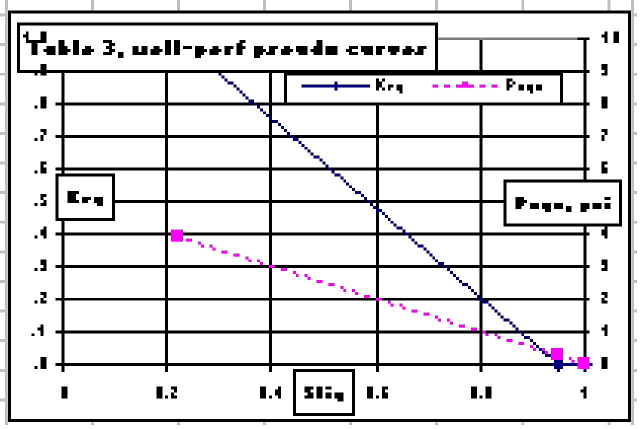


Table 3, well-perf pseudo curves

Sg	Sliq	Krg	Pcgo	
0	1	0	0	Lower end point
0.0496	0.9504	0	0.2474	Generated point
0.78	0.22	1	3.9	Upper end point

/



Original Rock Curves | Cell-Block Pseudo Curves | Well-Perf Pseudo Curves

Krow & Krog

SOF3

Table 1 rock curves

So	Sw	Krow	Krog	
0	1	0	0	Lower end point
0.2	0.8	0	0	Lower critical point
0.38	0.62	0.0043	0	Rock curve point
0.4	0.6	0.0048	0.004	Rock curve point
0.48	0.52	0.0529	0.02	Rock curve point
0.5	0.5	0.0649	0.036	Rock curve point
0.58	0.42	0.113	0.1	Rock curve point
0.6	0.4	0.125	0.146	Rock curve point
0.68	0.32	0.345	0.33	Rock curve point
0.7	0.3	0.4	0.42	Rock curve point
0.74	0.26	0.7	0.6	Rock curve point
0.78	0.22	1	1	Upper end point

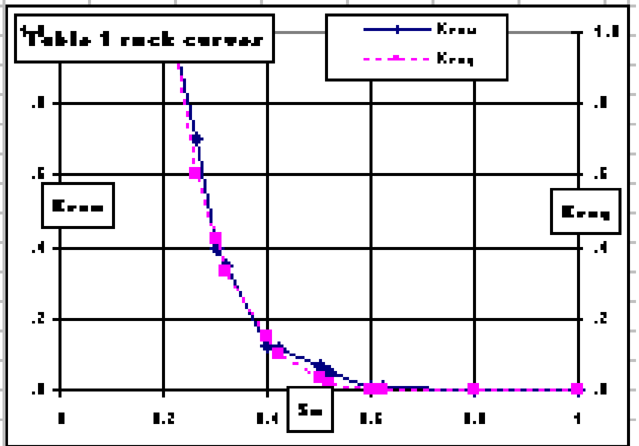


Table 2 cell pseudo curves

So	Sw	Krow	Krog	
0	1	0	0	Lower end point
0.0914	0.9086	0	0	Generated point
0.2736	0.7264	0.002	0.002	Generated point
0.3025	0.6975	0.0064	0.0064	Generated point
0.3126	0.6874	0.0119	0.0119	Generated point
0.3199	0.6801	0.0173	0.0173	Generated point
0.3357	0.6643	0.0331	0.0331	Generated point
0.3463	0.6537	0.0424	0.0424	Generated point
0.4742	0.5258	0.2613	0.2613	Generated point
0.6011	0.3989	0.3233	0.3233	Generated point
0.6998	0.3002	0.5355	0.5355	Generated point
0.78	0.22	1	1	Upper end point

/

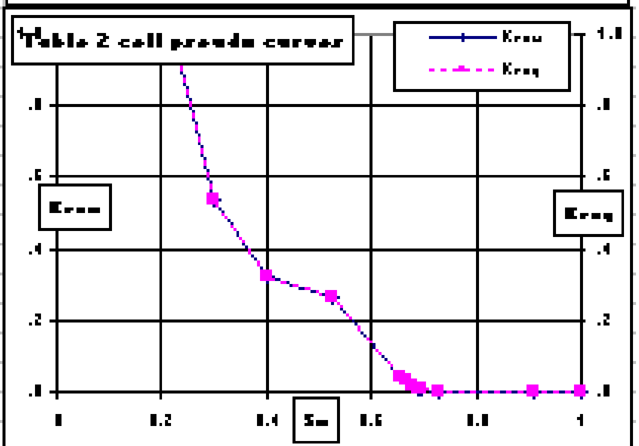
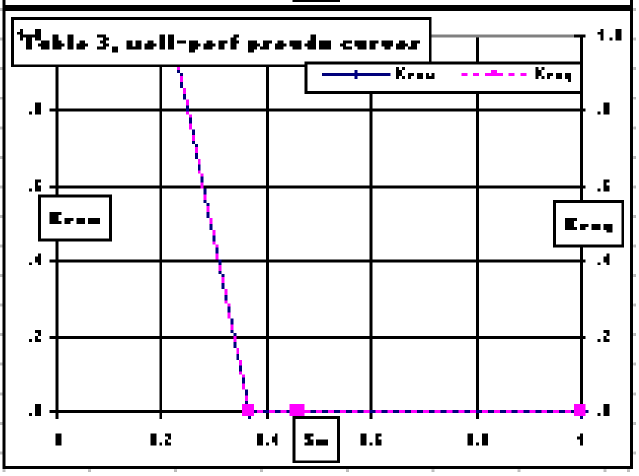


Table 3, well-perf pseudo curves

So	Sw	Krow	Krog	
0	1	0	0	Lower end point
0.5392	0.4608	0	0	Generated point
0.5405	0.4595	0	0	Generated point
0.635	0.365	0	0	Generated point
0.78	0.22	1	1	Upper end point

/



Original Rock Curves — Cell-Block Pseudo Curves — Well-Perf Pseudo Curves

SATNUM									
Table 1	Original Rock Curves								
Table 2	Cell-Block Pseudo Curves								
Table 3	Well-Perforation Pseudo Curves								
1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2
1	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1

Perfs

CAUTION: Some of PSEUDO's generalized curves contained ECLIPSE errors.
Typical errors included:
- non-monotonic curves and
- inconsistent Swc values (*i.e.*, Swc-Swc should be zero.)

The easy way to deal with this was to let ECLIPSE give error messages.

WISE ENGINEERS PROOFREAD EVERY LINE OF EACH INPUT FILE.
WISE ENGINEERS UNDERSTAND EVERY LINE OF EACH INPUT FILE.

Admittedly this is motivation by fear. The fear is that predictions based on faulty input will be used to make operational recommendations to management.

Make two kinds of changes to ECLIPSE *.DATA files when using pseudo curves.

1. Replace the rock-curve tables with the pseudo-curve tables.
2. Adjust to coarse-grid dimensions (from fine-grid dimensions.)

Copied from data / pseudo / chap1015_p / CHAP1015_P.DATA

```
     RUNSPEC     DIMENS      reduced to 10  1  15  (for coarse grid pseudo curves)
     RUNSPEC     UNIFOUT     deactivated
     RUNSPEC     UNIFIN      deactivated
     RUNSPEC     TABDIMS     NTSFUN increased for 11 pseudo-curve tables
     GRID        OUTRAD      added
     GRID        DRY         deactivated
     GRID        EQUALS      mod DTHETA, TOPS, DZ, PERMR, & PORO (for pseudo curves)
Eric modified to use 11 generalized pseudo curves (from 90x1x135 fine-grid)
     PROPS       SWFN        replace 1 rock-table with 11 pseudo-curve tables
     PROPS       SGFN        replace 1 rock-table with 11 pseudo-curve tables
     PROPS       SOF3        replace 1 rock-table with 11 pseudo-curve tables
     PROPS                   NOTE CORRECTIONS TO PSEUDO's pseudo-curve tables
     REGIONS     SATNUM      index of SWFN, SGFN, & SOF3 pseudo-curve tables by cell
     REGIONS     FIPNUM      modify for 10x1x15 grid (for pseudo-curves)
     SUMMARY     FOPR, FWPR, FGPR, & FVPR       added
     SUMMARY     FOPT, FWPT, FGPT, & FVPT  added
     SUMMARY     FGOR & WGOR 'PRODUCER'    added
     SUMMARY     FWGR & WWGR 'PRODUCER'    added
     SUMMARY     FWGR & WWGR 'PRODUCER'    added
     SUMMARY     FGLR & WGLR 'PRODUCER'    added
     SUMMARY     WBHP 'PRODUCER'           added
     SUMMARY     FPR        added
     SUMMARY     EXCEL      added
     SCHEDULE    RPTSCHED   5th integer (Rs) changed to 1
     SCHEDULE    COMPDAT    found error in 40x1x61
                            connection transmissibility factor
     SCHEDULE    COMPDAT    revised connection transmissibility factor
     SCHEDULE    COMPDAT    2nd to 5th variables locate coarse-grid perforations (for pseudo curves)
     SCHEDULE    COMPDAT    Chg 7th value (well-pseudo-curve-table#) to 9 (from default=0)
     SCHEDULE    COMPDAT    8th variable adjusts well-connection value (for pseudo-curves)
```

Make two kinds of changes to ECLIPSE *.DATA files when using pseudo curves.

1. Replace the rock-curve tables with the pseudo-curve tables.
2. Adjust to coarse-grid dimensions (from fine-grid dimensions.)

Copied from data / pseudo / chap3_5_p / rock_perf / CHAP3_5_P.DATA

```
    RUNSPEC    DIMENS     reduced to 3 x 1 x 5  (for coarse grid pseudo curves)
    RUNSPEC    UNIFOUT    deactivated
    RUNSPEC    UNIFIN     deactivated
    RUNSPEC    TABDIMS    NTSFUN increased for 13 pseudo-curve tables
    GRID       OUTRAD     added
    GRID       DRV        deactivated
    GRID       EQUALS     mod DTHETA, TOPS, DZ, PERMR, & PORO (for pseudo curves)
Eric modified to use 11 generalized pseudo curves (from 90x1x135 fine-grid)
    PROPS      SWFN       replace 1 rock-table with 13 pseudo-curve tables
    PROPS      SGFN       replace 1 rock-table with 13 pseudo-curve tables
    PROPS      SOF3       replace 1 rock-table with 13 pseudo-curve tables
    PROPS      SWFN       replaced 1 table with 13 tables
                          Table 12 = perforations (NOT the completion cell)
                          Table 13 = rock curves
    These are Kyte and Berry (rate-dependent) pseudo curves
    PROPS                 NOTE CORRECTIONS TO PSEUDO's pseudo-curve tables
               WARNING    Make sure Swc +(So)max = 1 (where (So)max = 1-Swc
               WARNING    Make sure curves are monotonic AND increasing
    REGIONS    SATNUM     index of SWFN, SGFN, & SOF3 pseudo-curve tables by cell
    REGIONS    FIPNUM     modify for 3 x 1 x 5  grid (for pseudo-curves)
    SUMMARY    FOPR, FWPR, FGPR, & FVPR        added
    SUMMARY    FOPT, FWPT, FGPT, & FVPT  added
    SUMMARY    FGOR & WGOR 'PRODUCER'    added
    SUMMARY    FWGR & WWGR 'PRODUCER'    added
    SUMMARY    FWGR & WWGR 'PRODUCER'    added
    SUMMARY    FGLR & WGLR 'PRODUCER'    added
    SUMMARY    WBHP 'PRODUCER'           added
    SUMMARY    FPR       added
    SUMMARY    EXCEL     added
    SCHEDULE   RPTSCHED  5th integer (Rs) changed to 1
    SCHEDULE   COMPDAT   found error in 40x1x61
                         connection transmissibility factor
    SCHEDULE   COMPDAT   revised connection transmissibility factor
                         2nd to 5th variables locate coarse-grid perforations (for pseudo curves)
                         Chg 7th value (well-pseudo-curve-table#) to 12 (from default=0)
                         8th variable adjusts well-connection value (for pseudo-curves)
```

Three groups of four charts present the results.

The same 12 charts are repeated for each ECLIPSE (simulation) run.

The three groups are: ratios, rates, and cumulative production.

The ratio group includes:

water cut,

produced gas-oil ratio, and

flowing bottom-hole pressure.

The rate group includes:

oil rate,

water rate,

gas rate, and

enlarged Pwf highlights the switch to Pwf control (from oil-rate control.)

The cumulative group includes:

total oil,

total water

total gas production, and

average field pressure.

There are six pseudo curves for each coarse-grid cell and each perforation.

Four are for relative permeability (Krw, Krg, Krow, and Krog.)

Two are for capillary pressure (Pcow and Pcgo.)

All of the initial pseudo curves provide good starting points.

All the initial pseudo curves will require manual adjustment before the coarse-grid reproduces the fine-grid results.

The numbers of pseudo curves (66 and 78) imply considerable (and very likely prohibitive) labor will be required to make the manual adjustments.

The initial match is better with the 11 sets of manually-grouped pseudo-curves developed for the 10 x 1 x 15 model.

Even though this is concrete evidence of my skill, I must acknowledge that it took more than three days to produce the 11 sets.

Past experience says it will take at least one day to manually modify each set of pseudo curves. Thus, 11 sets will likely take more than 11 days of manual adjusting.

This suggests that while PSEUDO is a great tool there is a practical limit to the number of cost-effective pseudo curves.

Perhaps it is more cost effective to start with straight-line pseudo-curves. This puts the engineer in a better position to adjust curvatures with Corey exponents and with the lambda factor (WorkBench.)

WISDOM

The ultimate goal is to have only three sets of (up to six) curves. This is 1 set of rock curves, 1 set of cell-block pseudo curves, and 1 set of well-perforation pseudo curves.

The discussion about the 11-pseudo-curve case opens the topic of adjusting the well productivity index (well-completion factor) as a way to get coarse-grid results to match the fine grid output.

Adjusting the productivity index seems to lack a physical basis.

At least two PhDs demonstrated superior matches with non-physical changes.

- This was an academic study of negative relative permeability.
    - This implies reverse flow from low pressure to high pressure.

My own experience indicates non-physical adjustments can provide a good match.

- That experience met substantial resistance from more experienced engineers.
- An equal match was achieved with a more conventional relative permeabilities.

Perhaps it is better to find a match that has a comfortable physical meaning.

- This provides the audience (chiefs, managers, and officers) with more comfort.

Discussion - Pseudo-Curve Cases

This study generated three pseudo-curve cases:

- 11 saturation tables for the 10 x 1 x 15 model,
- 13 saturation tables for the 3 x 1 x 5 model, and
- 3 saturation tables for the 10 x 1 x 15 model.

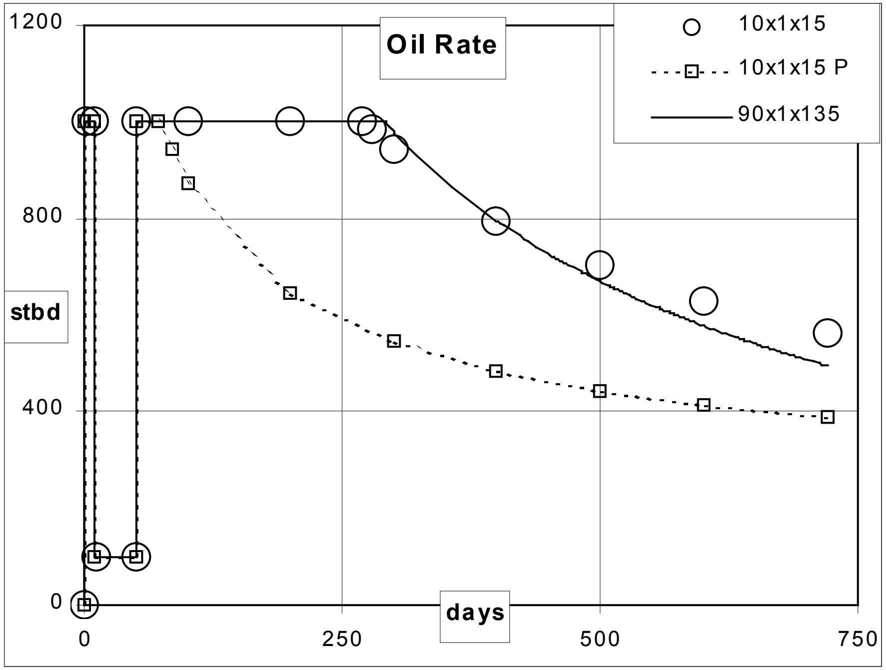
Each pseudo-curve case has a discussion that precedes 12 charts.

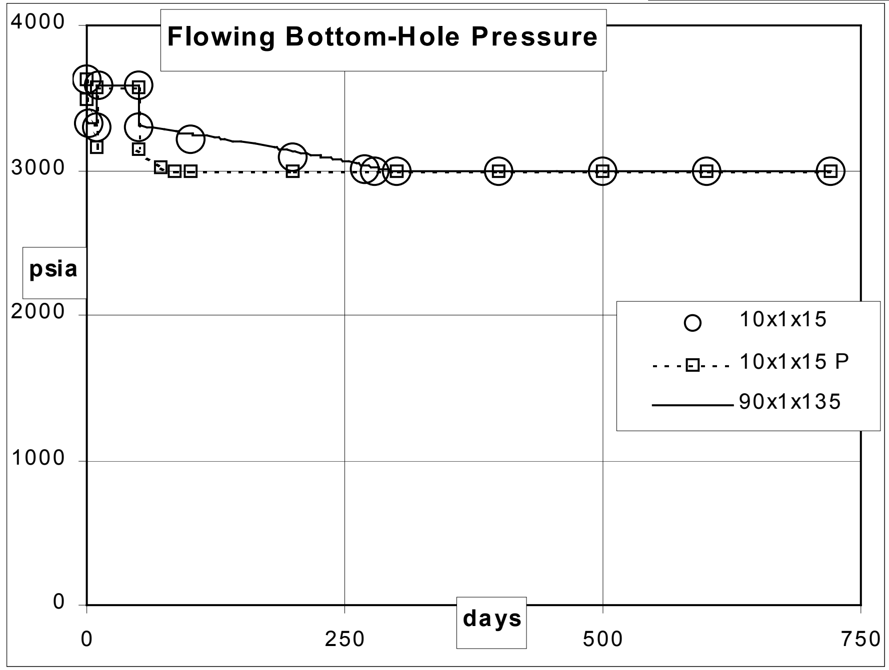
All the charts indicate the well canNOT sustain the 1,000 stbd production rate. The charts also indicate significantly less water coning and significantly less gas coning. This intuitively seems more likely to be a relative-permeability issue than a capillary-pressure issue. (The scope of this study excludes testing the hypothesis.)

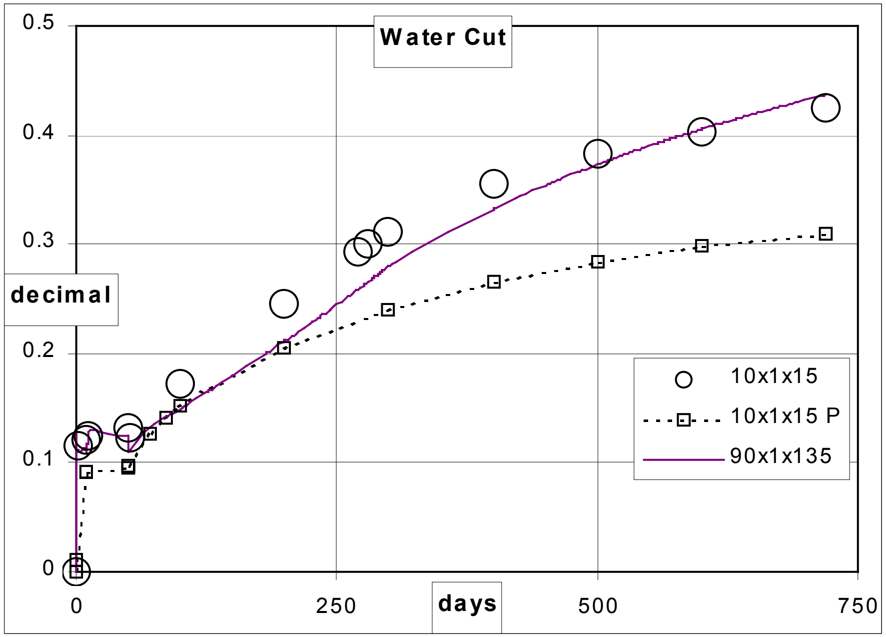
There are at least three possible explanations:

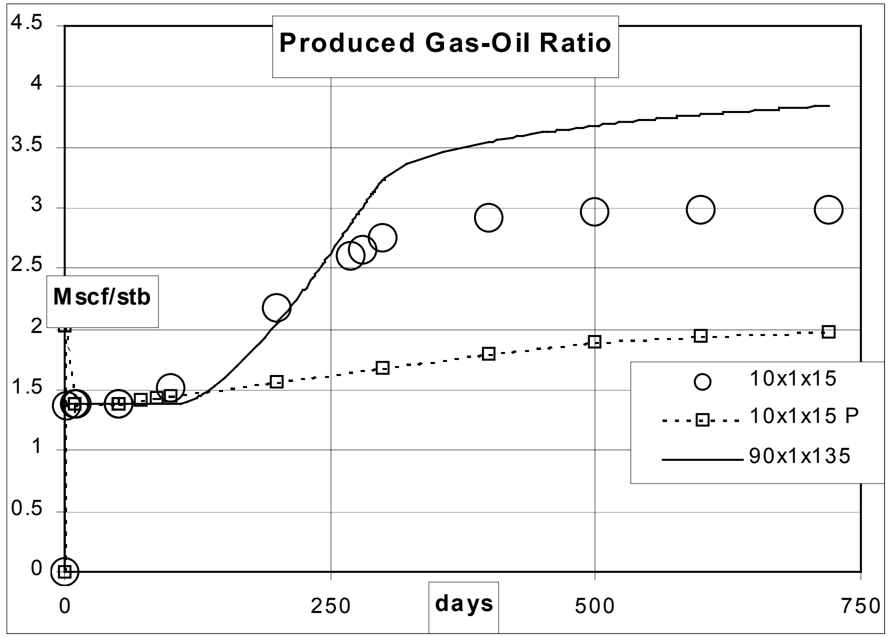
- The well-perforation pseudo curves are too restrictive,
  - This seems the most likely of the three
    - See the discussion of the 3 x 1 x 5 model results for more of this topic.
- The cell pseudo curves are too restrictive, or
  - It is difficult to guess which of the 36 relative permeability curves to change.
  - An alternative is to create a single set of pseudo curves for the entire grid.
- The productivity index need to be increased.
  - My experience suggests that even though this may work, it is non-physical.
    - See the discussion of the 3 x 1 x 5 model results for more of this topic.

10 x 1 x 15 Model (11 Saturation Tables) - Ratio Charts



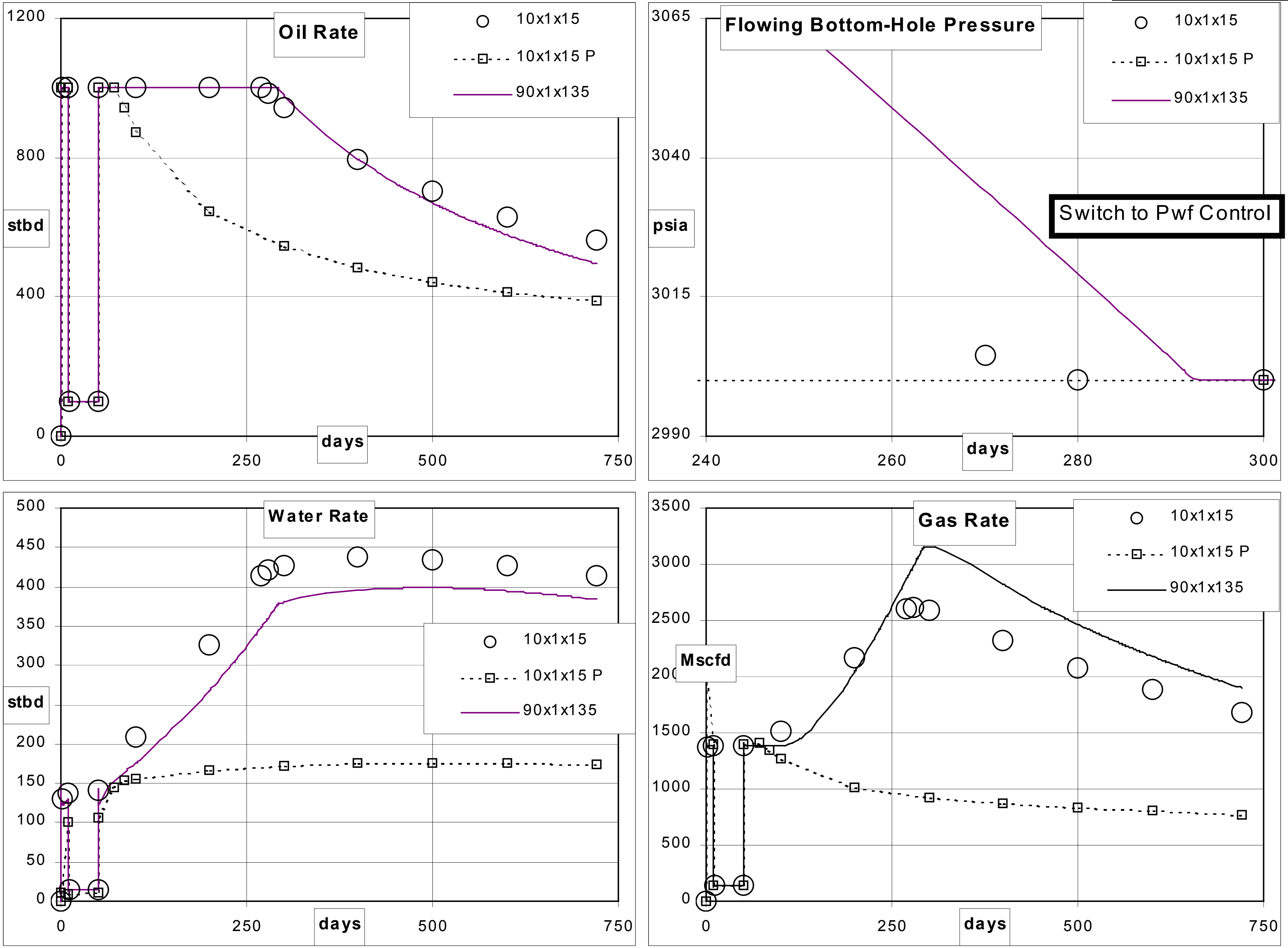






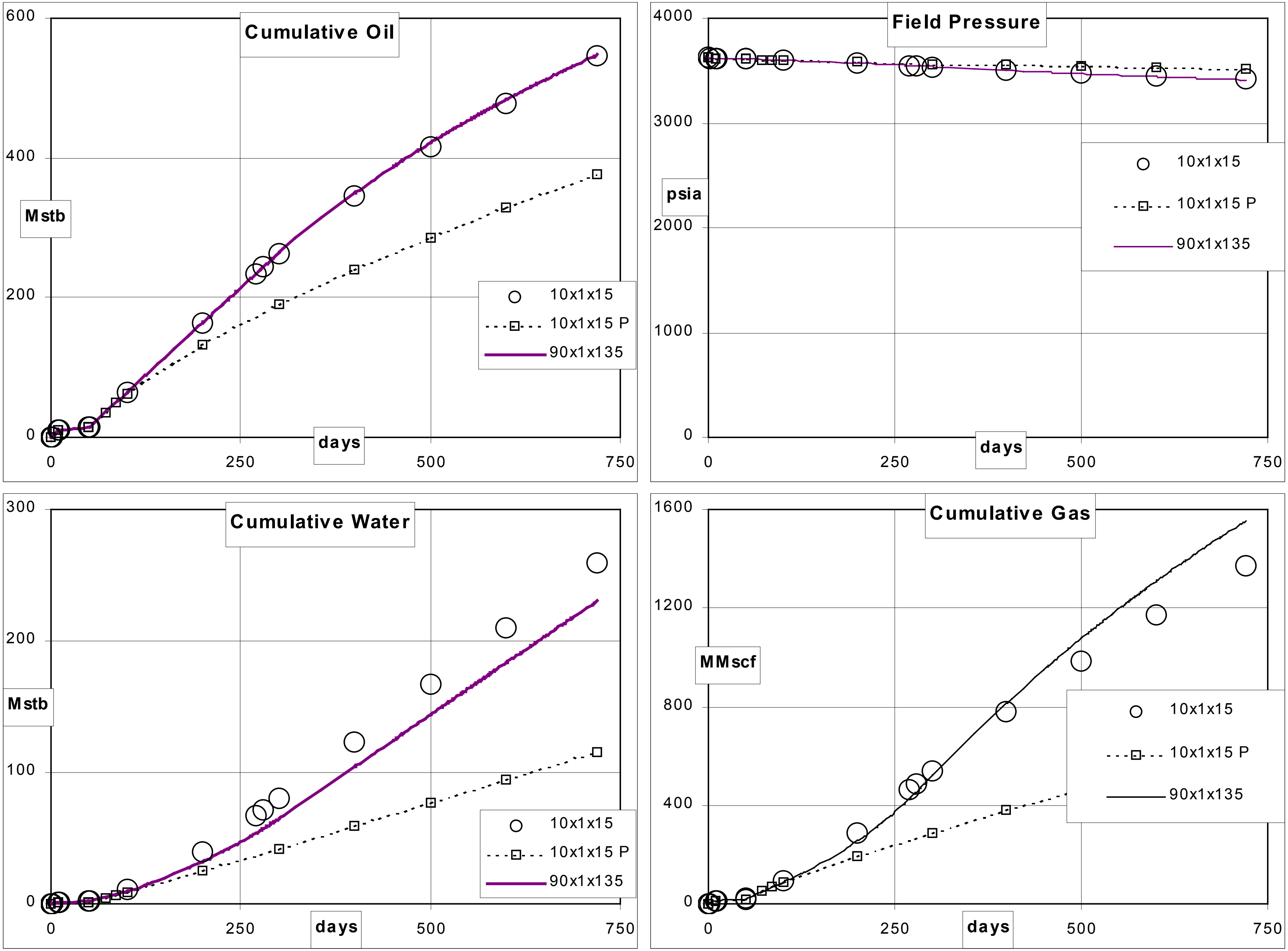
10 x 1 x 15 Model (11 Saturation Tables) - Rate Charts

Laine & Associates, Inc.
www.EricLaine.com



10 x 1 x 15 Model (11 Saturation Tables) - Cumulative Charts

Laine & Associates, Inc.
www.EricLaine.com



The 3 x 1 x 5 model includes two additional cases:

- Replace the well-perforation pseudo curves with the original rock curves, and
- Increase the well productivity by 10,000 percent (a factor of 100.)

All the charts indicate the well's ability to sustain the 1,000 stbd oil-production rate is significantly influenced by the well-perforation pseudo curves.

The pseudo curves (from PSEUDO) predict a dry hole.

Substituting the original rock curves for the well-perforations predicts the well comes much closer to sustaining the target oil rate.

First guesses for improving the oil rate include:

- Increasing the Krow and/or Krog values, and
- Reducing the residual So.

Using the original rock curves for the well-perforations over predicts both water coning and gas coning.

This is consistent with my experience to date.

A basic way to limit coning (delay breakthrough) is to modify the saturation end points.

This means increasing critical Sw and increasing critical Sg.

It is valuable to note that the 100-fold productivity increase had no effect when PSEUDO's well-perforation pseudo curves are used.

This conveniently removes the temptation to make a non physical change.

Analysis of the following charts suggests the possibility of adjusting only the well-perforation pseudo curves when matching coarse-grid and fine-grid results.

Intuition suggests it may be unwise to use the local properties of a well to compensate for the distributed flow characteristics of a large area.

The limited scope of this study prohibits studying the following hypotheses.

Analysis of the following charts also suggests the strong possibility of matching coarse and fine model performance by using only a single set of adjusted, grid-block, pseudo curves.

This is consistent with my personal experience.

3 x 1 x 5 Model (13 Saturation Tables) - Ratio Charts

Laine & Associates, Inc.
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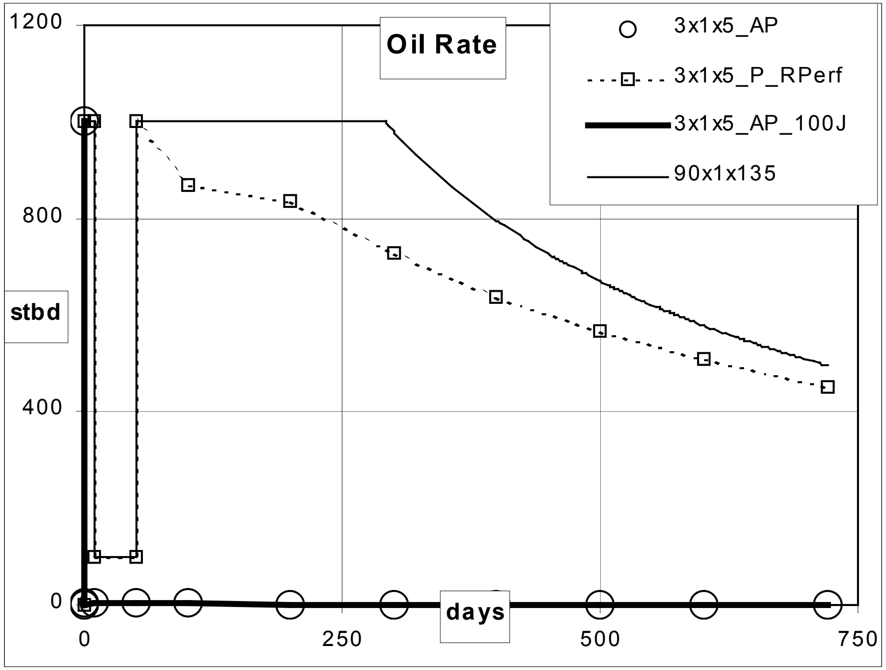
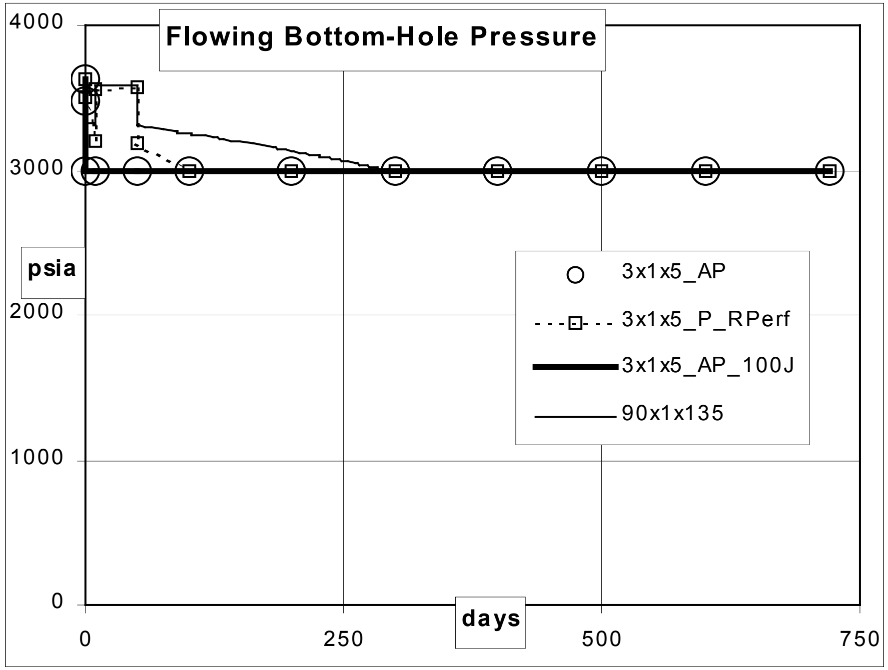
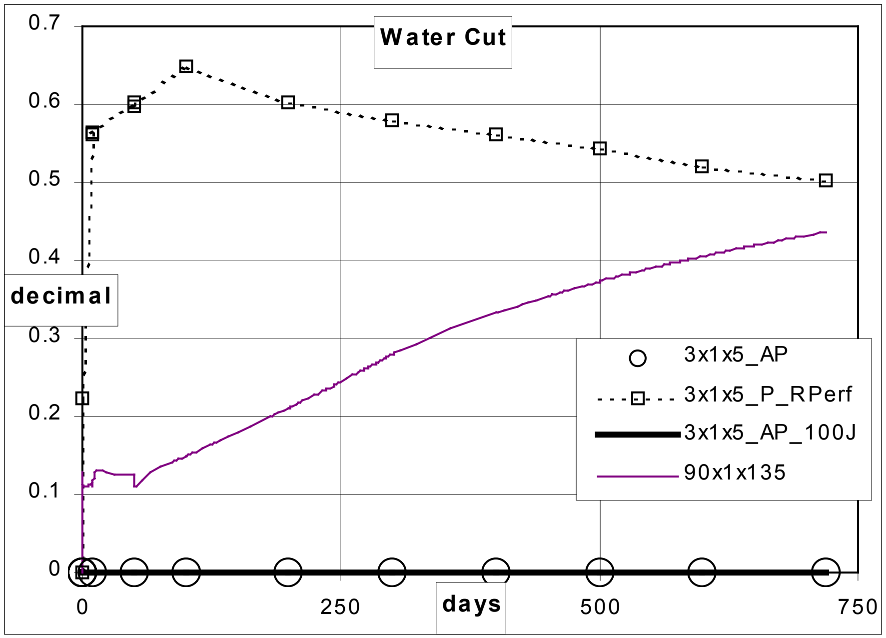
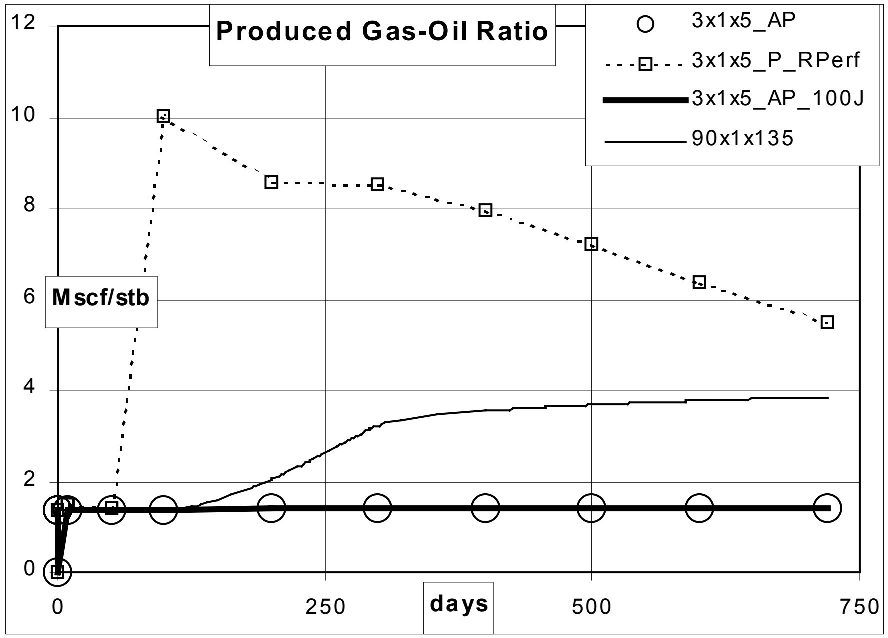
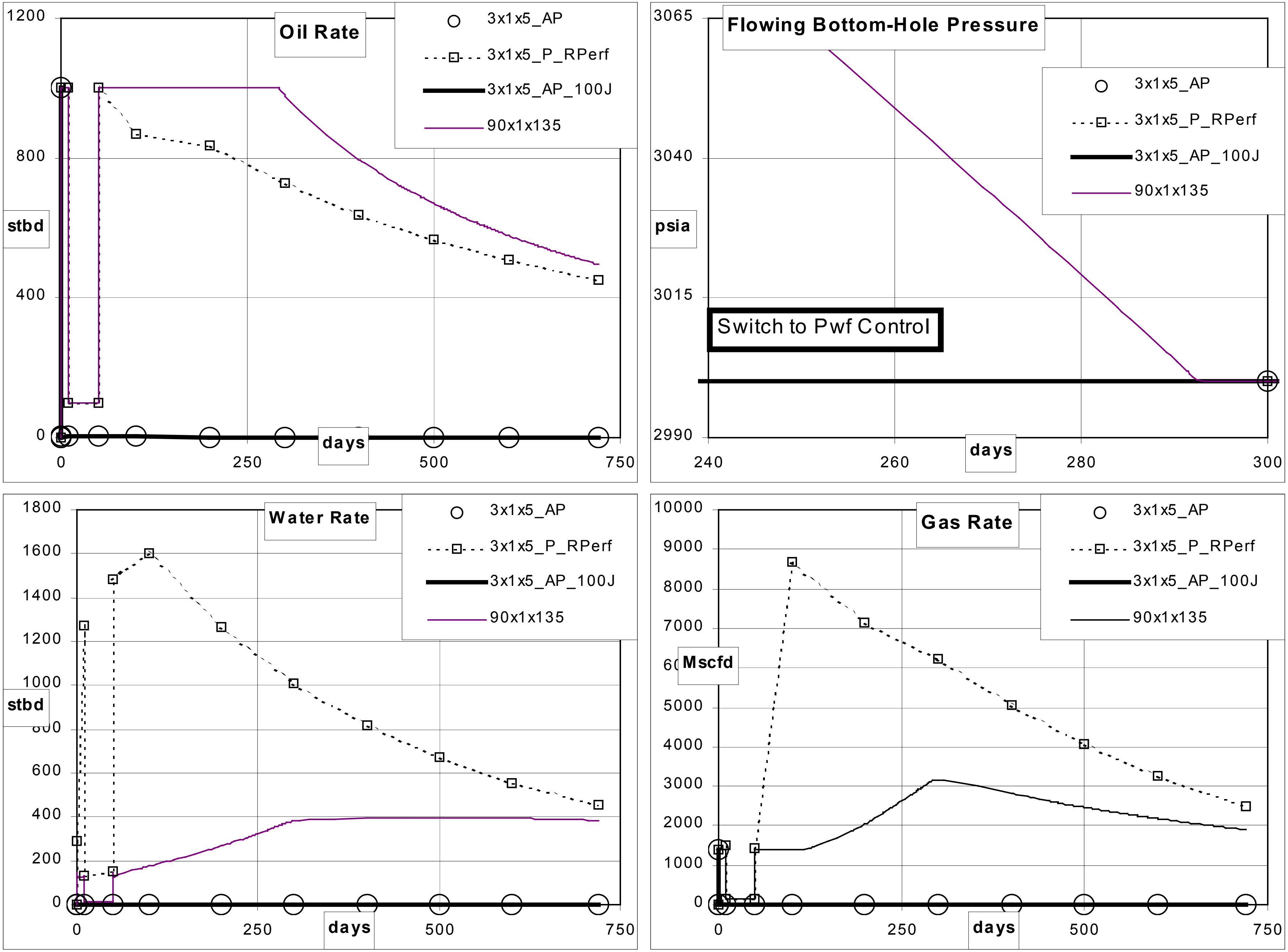








3 x 1 x 5 Model (13 Saturation Tables) - Rate Charts



3 x 1 x 5 Model (13 Saturation Tables) - Cumulative Charts

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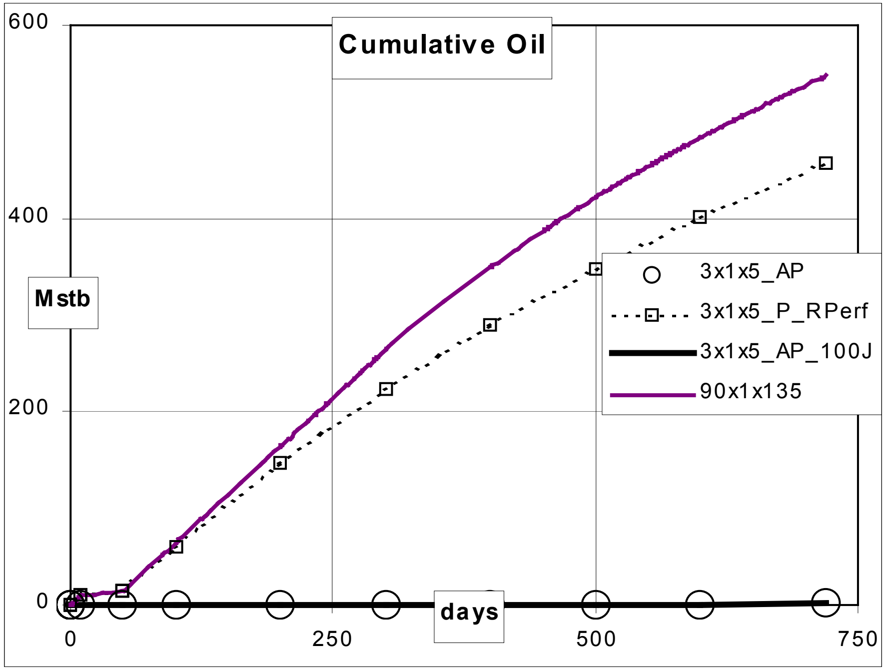
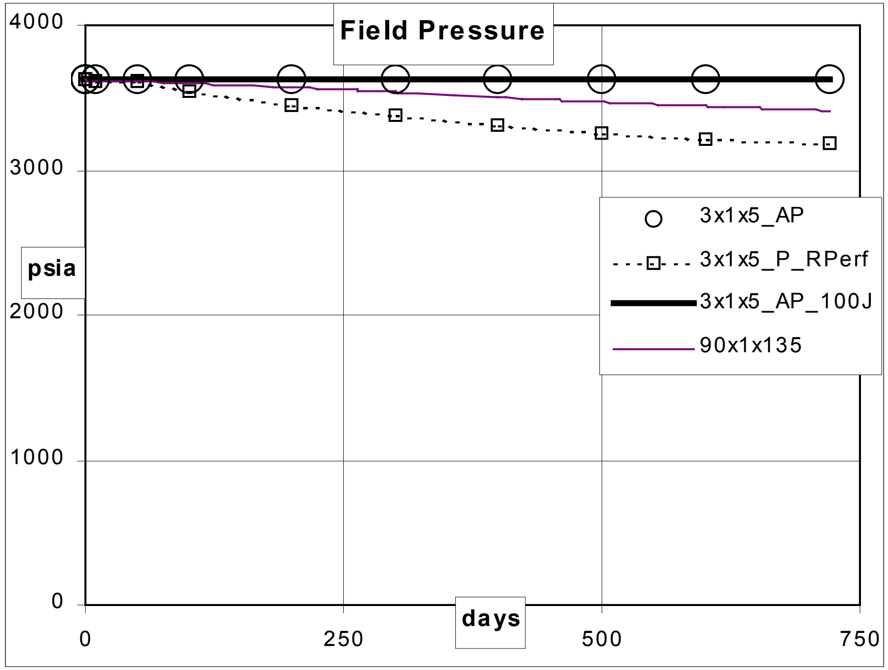
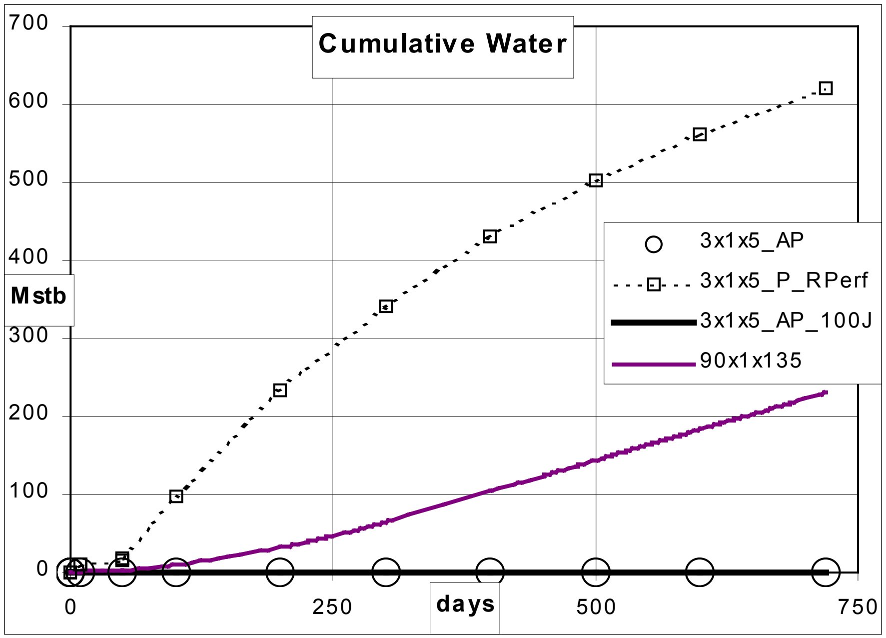
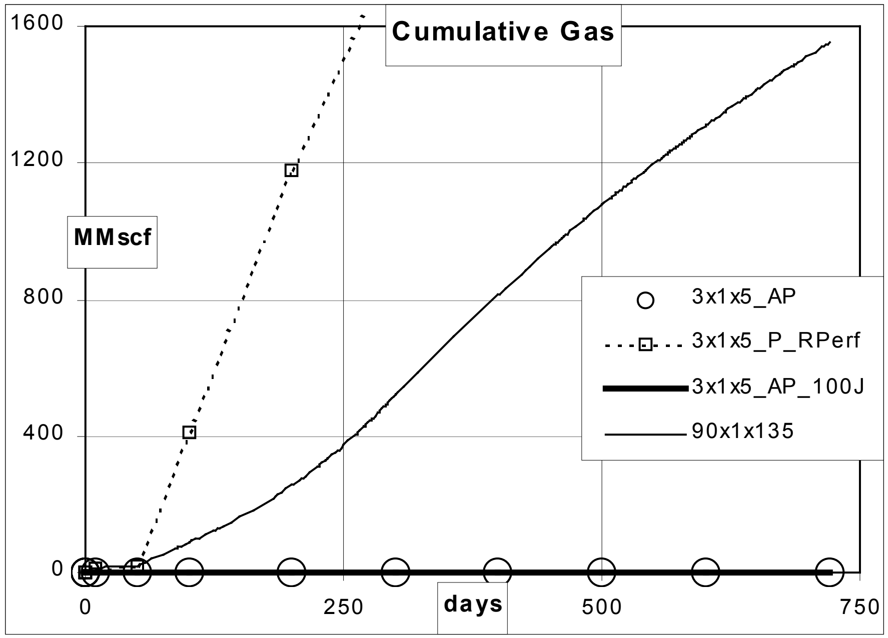








Using a single pseudo curve for the cells (supplemented the original rock curves in the gas cap and in the aquifer) looks like a big improvement. Two sets of saturation tables now apply to all the grid blocks.

It may be better to eliminate the rock curves and have only one set of pseudo curves.

This leaves the engineer with a manageable number of parameters to adjust.

Now all the charts indicate the well sustains the 1,000 stbd oil-production rate TOO LONG. The charts also indicate gas coning is closer to a match than water coning.

Both coning rates peak when the well switches from oil-rate control to flowing-bottom-hole-pressure control.

The water rate starts high and stays high.

The gas rate starts about right but soon drops below the (90x1x135) match line.

Notice that the changing the well-perforation curves has no noticeable effect.

This points to adjusting the cell pseudo curves as a (good) way to match the fine-grid predictions with a coarse grid.

An intuitive sequence starts with Krow and Krog reductions (to match the switch from oil-rate control to flowing-bottom-hole-pressure control.) Then reduce Krw (to match the water cut.) Then increase Krg while increasing the curvature (to maintain the early-time gas rate.)

In reality, each change may substantially interact with other characteristics. (If it was easy, anybody could do this.)

WISDOM

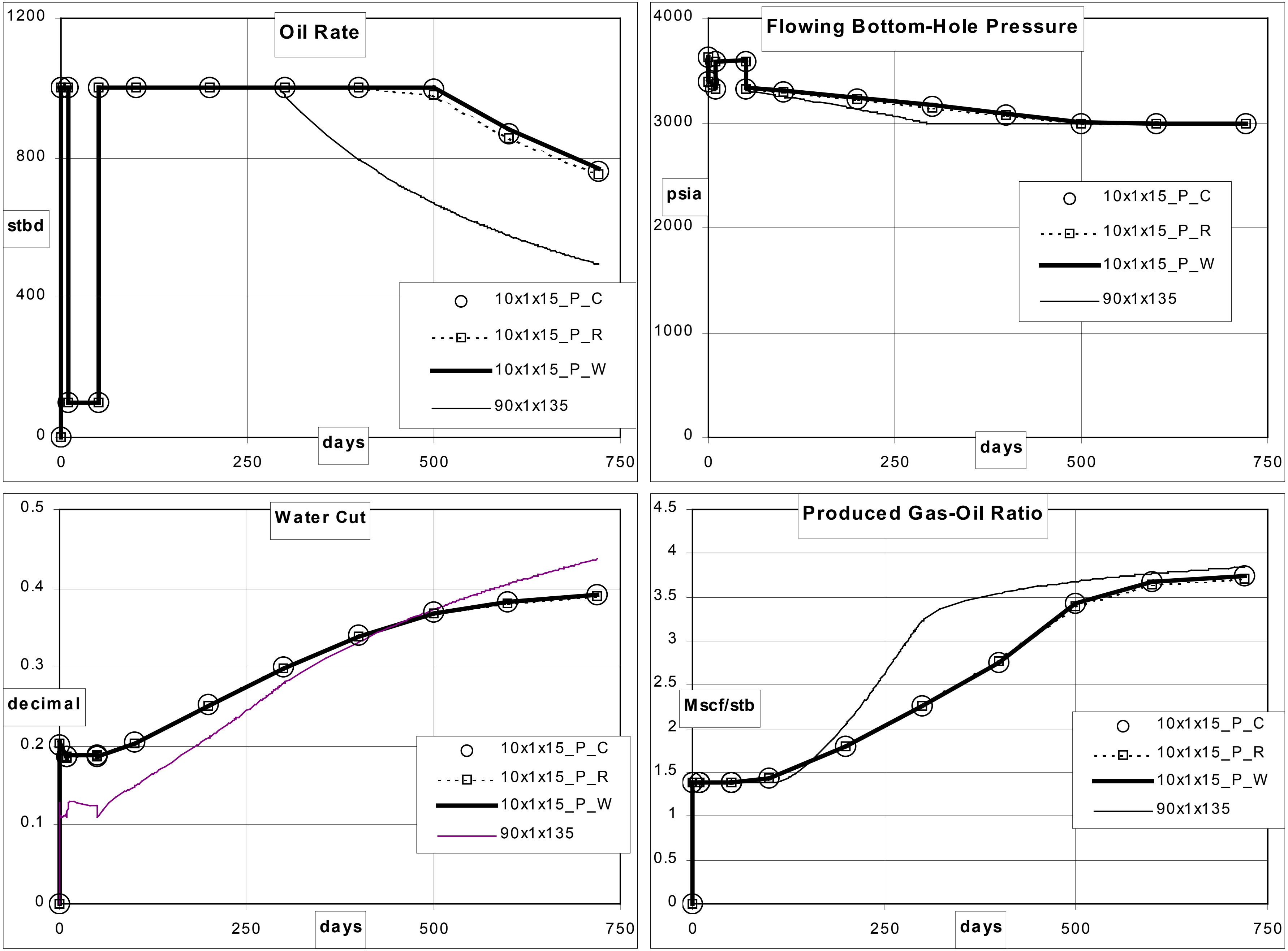
It may be better to eliminate the rock curves and have only one set of pseudo curves. This leaves the engineer with the minimum number of parameters to adjust.

one set of grid-block pseudo curves, and

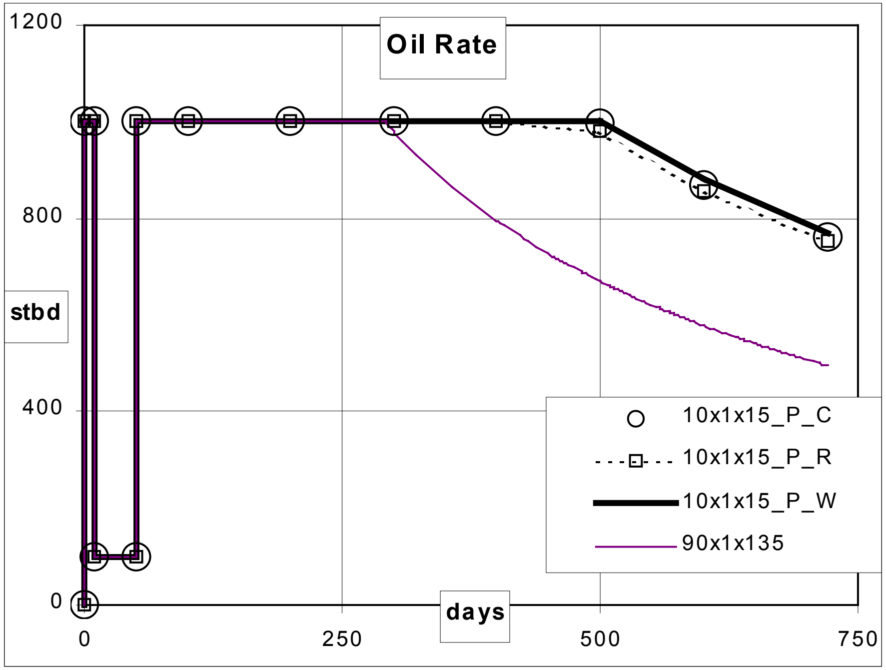
one set of well-perforation curves.

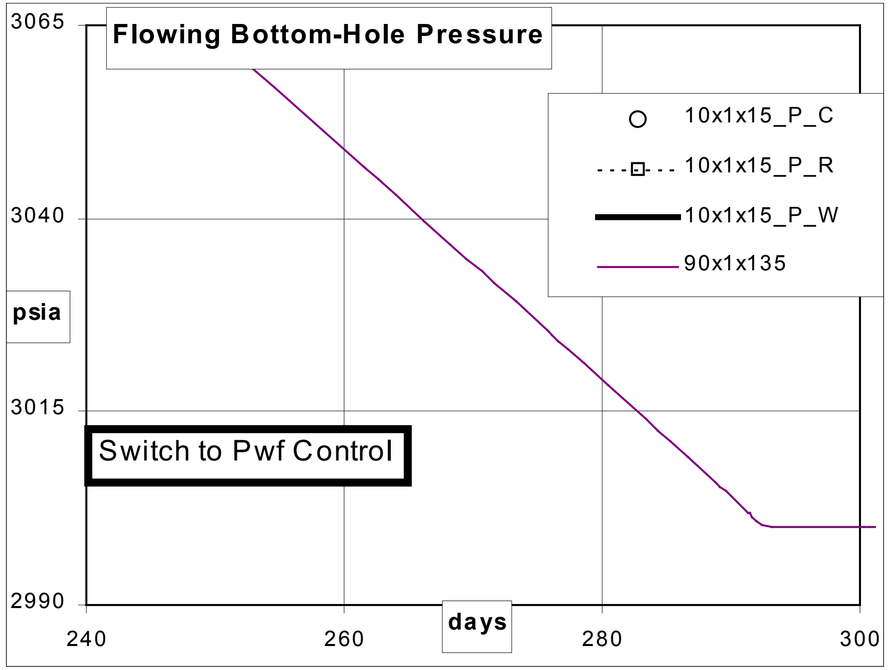
A reality of pseudo curves is that everybody would be able to do it if it was easy.

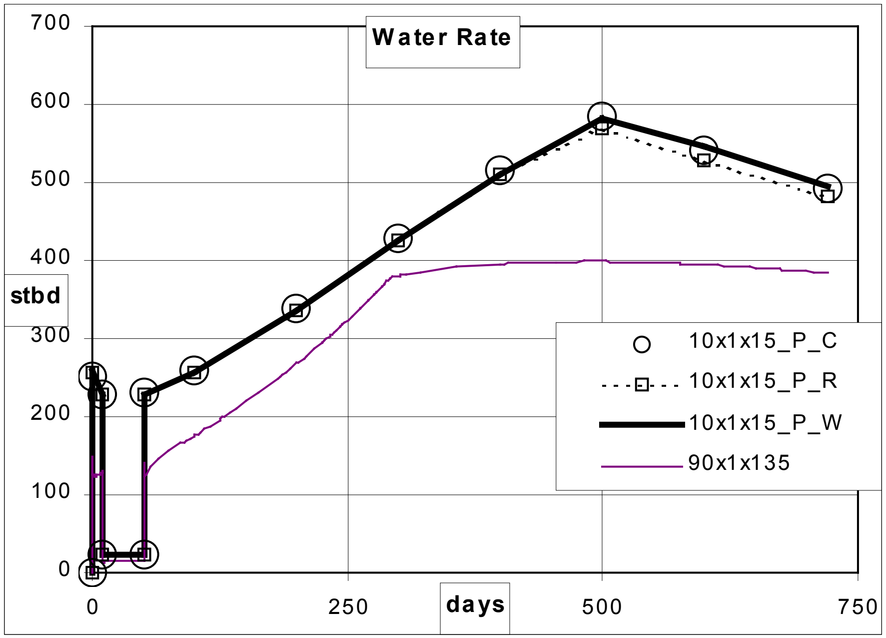
10 x 1 x 15 Model (3 Saturation Tables) - Ratio Charts

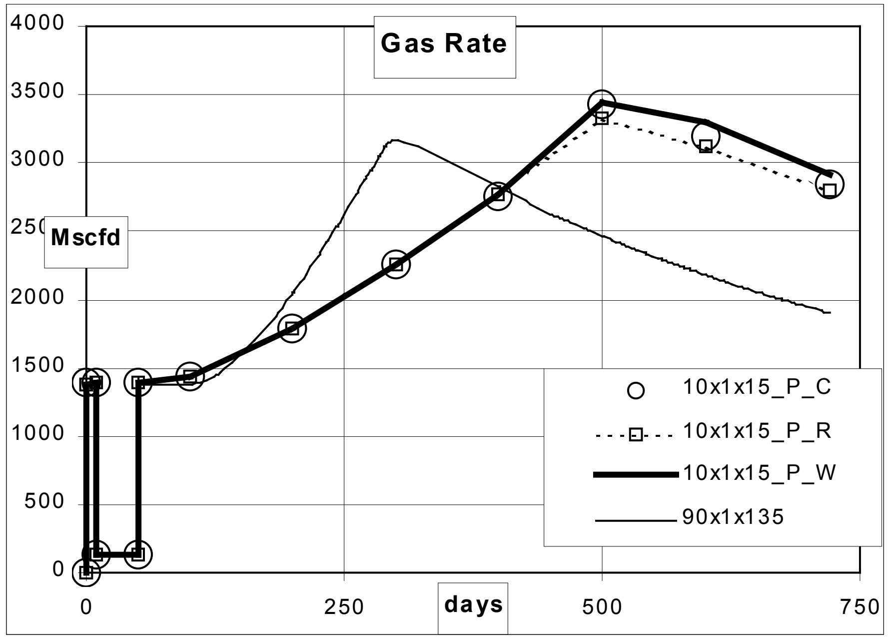


10 x 1 x 15 Model (3 Saturation Tables) - Rate Charts

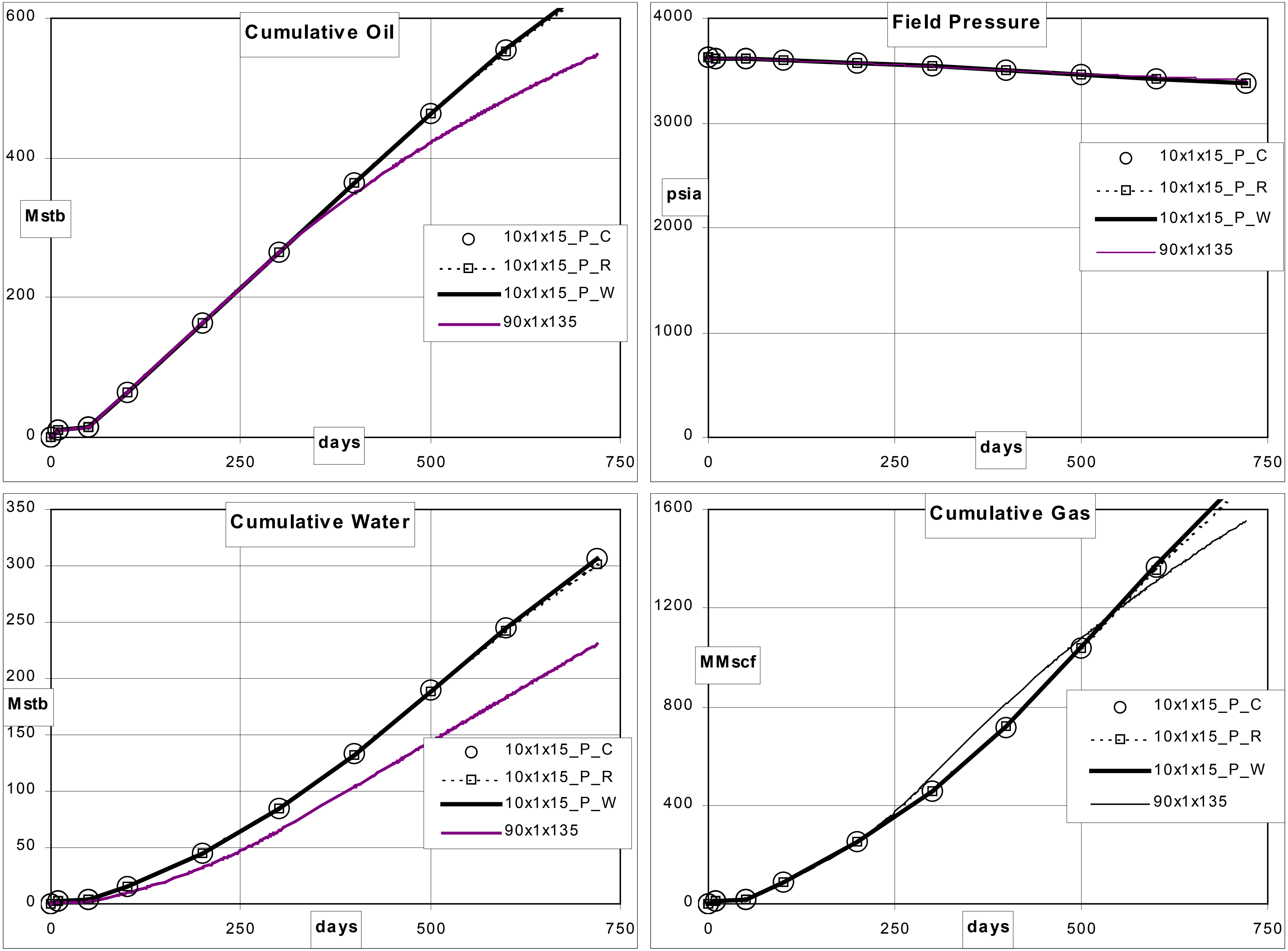








10 x 1 x 15 Model (3 Saturation Tables) - Cumulative Charts



This tutorial provides good guidance to the novice and the casual PSEUDO users.

PSEUDO is a quick way to get sophisticated starting points for pseudo curves.

It is important to resist the temptation to overly complicate the adjustment process.

All pseudo curves need adjustment before coarse-grid and fine grid results match.

Try to combine entire rock regions with a single set of cell pseudo curves.

Try to combine all wells with a single set of well-perforation pseudo curves.

First adjust the cell (grid-block) pseudo curves to match coarse and fine results.

Lastly, adjust the well-perforation pseudo curves to match water and gas coning.

It may be more cost effective to use end points and Corey's equations for the relative-permeability portion of the adjustment process.

It may be more cost effective to use the lambda factor for the capillary-pressure portion of the adjustment process.

Appendix - 90 x 1 x 135 Simulation Results Table

90 x 1 x 135

SHORT SUMMARY OF 90 X 1 X 135 VERSION OF Weinstein, Chappalear, and Nolan

TIME	FOPR	FWPR	FGPR	FVPR	FOPT	FWPT	FGPT	FVPT	WWCT	WGOR	WWGR	WGLR	WBHP	FPR
DAYS	stbd	stbd	Mscfd	rbpd	Mstb	Mstb	MMscf	Mrb		mscf/stb	stb/mscf	mscf/st	psia	psia
									wellname	PRODUCER				
0	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	3628	3621
0.001	1000	147.91	1344.47	1252.11	0.001	0.00015	0.00134	0.00125	0.129	1.344	0.110	1.171	3415	3621
10	1000	129.97	1383.38	1239.34	10	1.26044	13.8064	12.3501	0.115	1.383	0.094	1.224	3313	3617
10.002	100	12.42	132.14	122.53	10.0002	1.26046	13.8067	12.3503	0.110	1.321	0.094	1.175	3559	3617
50	100	14.22	138.42	125.18	14	1.83924	19.3406	17.3667	0.125	1.384	0.103	1.212	3591	3615
100	1000	175.27	1381.16	1284.69	64	9.70583	88.4575	80.705	0.149	1.381	0.127	1.175	3251	3598
200	1000	268.04	2043.94	1812.16	164	32.1275	255.14	232.57	0.211	2.044	0.131	1.612	3133	3571
300	980.1644	380.33	3159.69	2670.11	263.909	64.7977	519.587	459.785	0.280	3.224	0.120	2.322	3000	3538
400	795.5256	395.78	2821.49	2435.29	349.043	103.989	814.469	712.074	0.332	3.547	0.140	2.368	3000	3503
500	670.2502	398.79	2464.59	2196.16	421.5	143.784	1076.71	942.56	0.373	3.677	0.162	2.305	3000	3470
600	578.5914	394.67	2180.29	1993.85	483.63	183.507	1308.2	1151.6	0.406	3.768	0.181	2.240	3000	3442
720	495.0418	384.21	1900.50	1787.78	547.666	230.252	1551.97	1377.76	0.437	3.839	0.202	2.161	3000	3411
	qo	qw	qg	voidage	oil cum	water	gas cum	res vol					Pwf	Pavg